91602
new 82-10

LEGAL NOTICE

This report was prepared by Ontario Hydro and, while effort has been made to assure the accuracy and applicability of the material contained herein, neither Ontario Hydro nor any person acting on its behalf:

(a) makes any warranty, express or implied with respect to the accuracy, completeness, usefulness, method or process disclosed in this report or that such use may not infringe privately owned rights; or

(b) assumes any liability with respect to the use of, or for damages resulting from the use of, any information, apparatus, method or process disclosed in this report.

COMPLIMENTARY COPY
Please Credit Ontario Hydro Research if Reproduced in Whole or in Part

ontario hydro
research division

FREDERICK HOUSE LAKE DAM
EVALUATION OF CONCRETE
FOR ALKALI-AGGREGATE REACTIVITY

Report 91-239-K

E.J. McColm
Engineer
Concrete Technology Section
Civil Research Department

ABSTRACT

Concrete from Frederick House Lake Dam (constructed from 1937 to 1938) was evaluated for alkali-aggregate reactivity. Specimens prepared from aggregate obtained from stockpiles at the site and from a concrete core drilled from the south gravity section were subjected to long-term testing. The aggregate from the stockpiles was assumed to have been used in the construction of this dam. Specimens prepared from concrete cores drilled from various locations were petrographically examined. Based on the results of this evaluation, it appears that alkali-aggregate reactions have occurred in the concrete; however, they are considered as minor. It could not be determined whether or not the reactivity was responsible for the reported apparent expansion of the deck slabs.

job	file	date	report no.
42-197-281	842.5 FRE	December 31, 1991	91-239-K

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	REVIEW OF HISTORICAL INFORMATION	1
3.0	LABORATORY TESTING	2
3.1	Aggregates	2
3.2	Concrete Core	3
4.0	PETROGRAPHIC EXAMINATION	3
5.0	DISCUSSION	4
6.0	CONCLUSION	5
FIGURES 1 TO 8		6
APPENDIX A:	Review of Historical Information	13
APPENDIX B:	Concrete Core Log	20
APPENDIX C:	Petrographic Examination of Concrete Core	25
APPENDIX D:	Gravity Section and Spillway, Petrographic Examination of Concrete Core	38
DISTRIBUTION		last page

ontario hydro
research division

To Mr. O. Bernaus
Manager
Civil Maintenance Department
Hydraulic Generation Group

Attn: Mr. L.W. Coley/Mr. L.A. Young

FREDERICK HOUSE LAKE DAM
EVALUATION OF CONCRETE
FOR ALKALI-AGGREGATE REACTIVITY

E.J. McColm

1.0 INTRODUCTION

As requested by Mr. L.A. Young of the Civil Maintenance Department, an investigation was undertaken by the Concrete Technology Section, Civil Research Department, to evaluate the concrete in the Frederick House Lake Dam for alkali-aggregate reactivity (AAR). It was reported that apparent expansion of the concrete had caused the expansion joints to close and it had been necessary to saw-cut the deck slabs to relieve the build-up of stresses. The purpose of this investigation was to determine whether or not alkali-aggregate reactions were occurring in the concrete and whether the reactions could be causing the apparent expansion of the deck slabs. The activities undertaken for this investigation were as follows:

- Review historical information regarding materials used and tests carried out on the concrete.
- Perform laboratory testing
  - Carry out testing of aggregates obtained from the stockpiles at the site using the CAN/CSA-A23.2-14A test procedure.
  - Monitor the length change of specimens prepared from a concrete core drilled from the south gravity section.
  - Monitor the length change of core specimens stored in a NaOH solution and companion specimens stored in lime water.
- Petrographically examine specimens prepared from concrete cores drilled from various locations throughout the structure.

This report summarizes the results of the investigation.

2.0 REVIEW OF HISTORICAL INFORMATION

Frederick House Lake Dam is a control dam located on the Frederick House River. It consists of north and south gravity sections and a spillway (Figures 1 to 3). A review of construction records and reports was undertaken to obtain information regarding the materials used in the construction of this dam and any testing conducted on the materials or concrete.

Concrete was placed from 1937 to 1938. Pyramid brand cement from the St. Mary's mill and Canada brand cement from the Hull mill each supplied approximately half the cement. A small amount of Canada cement from the Belleville mill was used towards the completion of the project. Information regarding the alkali content of the cement could not be located. The mix proportions for the concrete used to construct this dam varied. The concrete initially containing 6.5 bags/yd^3 (569 lb/yd^3) of cement which was reduced to 5.5 bags/yd^3 (482 lb/yd^3) as the project progressed. The water/cement ratio varied between 0.50 and 0.70. The concrete had a specified compressive strength of 3000 psi at 28 days. The compressive strength of specimens prepared and tested during construction averaged 4175 psi at 28 days. Information regarding the materials used in the construction of this dam was obtained from Research Division Report S86-15-K.

An examination of two rock samples by J.E. Thomson of the University of Toronto was conducted in 1937. The results, given in Appendix A, Item 1, identified one rock sample as an altered diabase and the second sample as an altered quartz porphyrite. These aggregates were presumed to have been used in the concrete, and their description was consistent with the laboratory reference aggregate from this dam.

In 1984, a few chunks of concrete believed to be from Frederick House Lake Dam were examined to determine and comment on the possibility of AAR causing the distress observed (ie. cracking, squeezing of the joints) in the dam. The report summarizing the results of this examination is given in Appendix A, Item 2. A preliminary petrographic examination of the concrete identified the presence of AAR. The suspect aggregates were identified as greywacke and/or argillite.

In 1985 and 1986, specimens were prepared from laboratory reference aggregate from Frederick House Lake Dam. These specimens were tested for AAR using the ASTM C 227 test procedure (mortar-bar method). The results were reported in Research Division Report 90-210-K. The pertinent portions of this report have been included in Appendix A, Item 3. For this test procedure, CSA CAN3-A23.1 (Supplement No 2-1986) recommends that the expansion should not exceed 0.05% at 3 months or 0.10% at 6 months. Expansions above these limits would be considered deleterious. The specimens tested did not exhibit deleterious expansion; however, this test procedure is currently being reviewed.

This review of historical information identified two inconsistencies. First, the petrographic identification of the aggregates conducted in 1937 differed from that conducted in 1984. Second, standard testing for expansion due to AAR carried out in 1985 and 1986 using the ASTM C 227 test procedure did not find the aggregates from this dam to exhibit deleterious expansions, although it was reported that apparent expansion had occurred in the deck slabs of the structure and evidence of AAR was noted in the 1984 petrographic examination. As discussed later in this report, the results obtained in 1984 on the examination of a few chunks of concrete are not consistent with testing and examination of the concrete conducted as part of the evaluation reported here. The chunks of concrete may therefore not have been from this dam.

3.0 LABORATORY TESTING

3.1 Aggregates

Samples of coarse aggregate from stockpiles at the dam were obtained by the Rock Sciences Section and delivered to the Concrete Technology Section laboratory. The aggregate was examined and found to be petrographically similar to the coarse aggregate in the concrete core obtained from the south gravity section (see Section 3.2) and to the laboratory reference aggregate tested in 1985 and 1986. It is therefore probable that these stockpiles contain material remaining from the construction of the dam.

Specimens were prepared with the stockpiled aggregate and tested for potential expansion of cement-coarse aggregate combinations using test procedure CAN/CSA-A23.2-14A. The specimens consisted of concrete prisms (75x100x400 mm) which were stored at constant temperature and 100% relative humidity. One set of specimens was stored at 23°C and the second set was stored at 38°C. Length measurements were made periodically, and the change in length with time was used to evaluate the expansive tendencies of the cement-coarse aggregate combination. The results of these tests are summarized in Figures 4 and 5. As discussed in Section 5.0, no significant expansion of the specimens was observed.

3.2 Concrete Core

In 1989, the Rock Sciences Section, Civil Research Department, drilled a core vertically from the south gravity section of the dam (Figure 2). The core was drilled as part of an investigation of internal stresses in the dam, which is reported in Research Division Report 90-213-K. Specimens prepared from the core were monitored for length change in one of three environments as follows: stored in 100% relative humidity at 38°C; immersed in 1M NaOH solution at 23°C; or immersed in lime water at 23°C. Prior to preparing the specimens, the core sections were stored in the laboratory for approximately six months in 100% relative humidity at 23°C. A description of the concrete and core sections is given in Appendix B.

Specimens were stored in 100% relative humidity at 38°C to evaluate the potential for further expansion of the concrete. The specimens consisted of sections of the core cut to a uniform length of 250 mm with gauge pins fastened to the ends. The change in length with time, as plotted in Figure 6, was used to evaluate the potential for further expansion of the concrete. A maximum expansion of 0.03% was observed after approximately one and a half years of monitoring.

Specimens were also stored in a 1M NaOH solution at 23°C and companion specimens were stored in lime water to identify the presence of reactive aggregate and the potential for further expansion of the concrete. The specimens for this test consisted of 200 mm long core sections cut in half longitudinally. At two locations on the outside surface of each half, a set of length measurement gauges (Pfender) was attached. One half of the core was then placed in a 1M NaOH solution and the other half in lime water. Length measurements were made at various intervals and the change in length with time was used to evaluate the expansive tendencies of the concrete. The results of the tests are plotted in Figures 7 and 8. A maximum relative expansion of approximately 0.06% was observed after one and a half years of monitoring.

4.0 PETROGRAPHIC EXAMINATION

Polished specimens and thin sections were prepared for petrographic examination from the sections of core drilled from the south gravity section by the Rock Sciences Section in 1989. Research Division Report S90-47-K, attached as Appendix C, gives the results, which are summarized below.

The coarse aggregate used in the concrete, which was reportedly obtained from excavated bedrock from the dam site, consisted primarily of metasedimentary and metavolcanic migmatites. The laboratory reference aggregate and the material obtained from the stockpile at the site were similar to the coarse aggregate in the concrete. This aggregate was also similar to that identified in 1937. The fine aggregate was composed predominantly of granite gneiss and associated minerals with 1% to 2% by volume of chert. The fine aggregate was obtained from a pit near the site. Although evidence of alkali-aggregate reactivity was identified in the cores, the extent was minor and limited to a few alkali-silica gel filled cracks associated with metasedimentary and metavolcanic migmatite coarse aggregate and several sand-sized chert particles. Many of the coarse aggregate particles were cracked; however, the cracks generally did not extend into the cement paste and appeared to have been present in the aggregate before being used in the concrete. Minor discontinuous cracks were observed in the cement paste which in a few cases extended through the aggregates.

On June 12 and 13, 1991, several cores were drilled from the north and south gravity sections and the spillway deck and piers by the Concrete Technology Section (Figure 1). Appendix B contains the concrete core log which describes the cores. The purpose of obtaining these samples was to determine whether the aggregate used in the concrete varied and whether there was a difference in the extent of AAR with location in the dam. Polished specimens and thin sections were prepared from the cores and examined petrographically. The results are summarized in Research Division Report S91-21-K which is attached as Appendix D.

The concrete from the various locations, including that examined previously from the south gravity section, was found to be petrographically similar. Evidence of alkali-aggregate reactivity was identified in all of the core sections examined. The extent of alkali-aggregate reactivity did not vary significantly from location to location and was similar to that previously observed in the core drilled from the south gravity section in 1989.

5.0 DISCUSSION

The review of historical information found a discrepancy in the type of coarse aggregate used in the concrete. The aggregate identified in 1937, which was similar to the reference aggregate, differed from the aggregate identified in a chunk of concrete examined in 1984. Based on the petrographic examination of cores from several locations in the dam, the coarse aggregate used in the concrete was identified as consisting primarily of metasedimentary and metavolcanic migmatites and the fine aggregate as granite gneiss, quartz, feldspar with lesser amounts of greywacke, volcanic and carbonate rock fragments. A small amount of chert was also identified in the fine aggregate. No variation was noted in the composition of the concrete with location in the dam. The types of aggregate identified in the chunks of concrete examined in 1984 are not consistent with these results and may represent concrete from another structure.

The CAN/CSA-A23.2-14A test procedure suggests a maximum expansion at one year of 0.025% and 0.040% for specimens stored at 23°C and 38°C, respectively. Expansion values above these limits are considered potentially deleterious. As shown in Figures 4 and 5, the specimens containing coarse aggregate from the stockpiles did not exhibit expansion above that suggested by CSA, even after two years. These results are in agreement with the results of the ASTM C 227 test conducted in 1985 to 1986.

The monitoring of the core specimens for length change is a non-standard test procedure; therefore, expansion limits have not been set. If the limits suggested for test procedure CAN/CSA A23.2-14A are used for the core sections stored in 100% relative humidity at 38°C, then the maximum expansion at one year would be 0.04%. It can be seen that the specimens did not achieve this expansion. The monitoring of specimens stored in the NaOH solution with companion specimens stored in lime water has been conducted by others[1] who have used a maximum of 0.020% at 8 months for the differential expansion between specimens stored in the two solutions at 38°C. The specimens tested here were stored at 23°C; therefore, a lower expansion would be anticipated. As seen in Figure 6, the relative expansion was close to this limit and at later ages exceeded it. The significant expansion of the specimens stored in the NaOH solution and the lack of expansion of the specimens stored in lime water may indicate that reactive aggregates are present in the concrete, but sufficient alkalis are not available to cause further expansion.

The petrographic examination identified the presence of AAR in the concrete, but classified it as minor. Cracking observed in the cores was generally restricted to the aggregates, with minor discontinuous microcracking in the paste.

---

[1] Stark D, Depuy G, Alkali-Silica Reaction in Five Dams in Southwestern United States. Concrete Durability ACI SP100-90, Vol 2, 1987, pp 1759 to 1786.

6.0 CONCLUSIONS

1. Laboratory testing conducted as a part of this program using the CAN/CSA-A23.2-14A test procedure and that conducted in 1985 and 1986 using the ASTM C 227 test procedure both found that the specimens prepared with aggregate from Frederick House Lake Dam did not exhibit deleterious expansion.

2. Testing of core specimens from the south gravity section using non-standard procedures indicated that reactive aggregates might be present in the concrete. Significant expansion of some specimens was noted, but how this relates to the potential for future expansion of the concrete could not be determined

3. The composition of the concrete sampled from several locations in the dam was determined and found to be petrographically similar.

4. The petrographic examination of specimens from various locations in the structure identified evidence of AAR, but classified it as minor. The concrete appeared in good condition and only exhibited minor discontinuous cracking in the cement paste.

5. Although some expansion of the concrete may be attributed to alkali-aggregate reactions, it could not be determined whether this mechanism was responsible for the reported apparent expansion observed in the deck slabs.

Approved by:

J.B. Brown
Manager
Civil Research Department

Prepared by:

E.J. McColm
Engineer
Concrete Technology Section

Reviewed by:

G.S. Kellay
Supervising Engineer
Concrete Technology Section
Civil Research Department

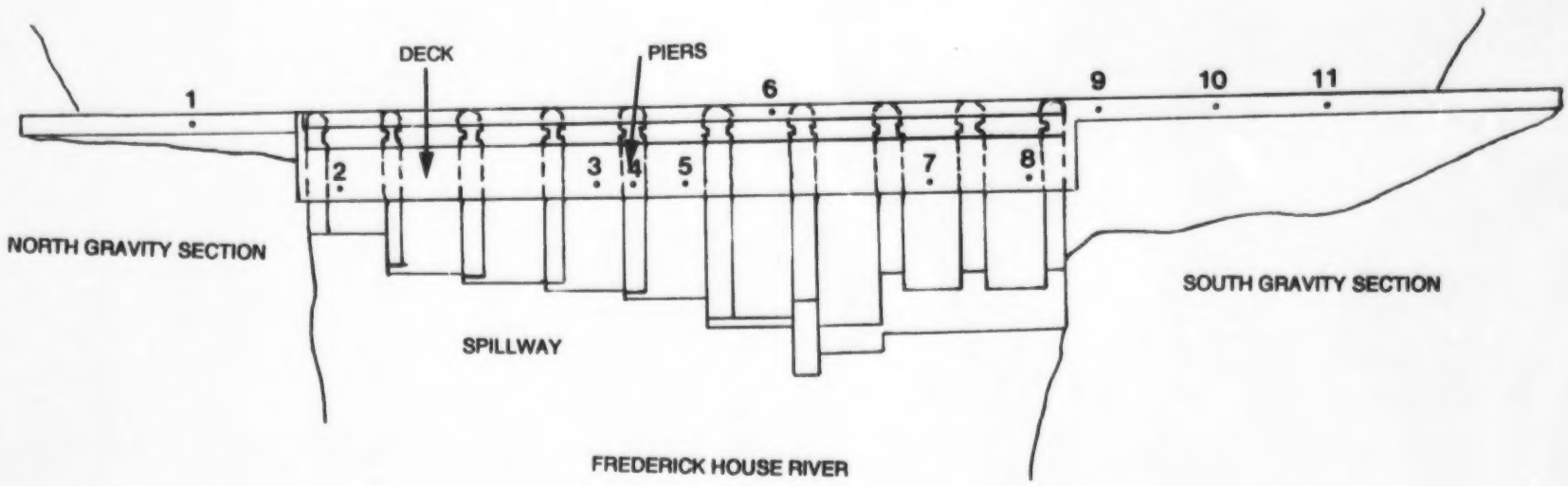


FIGURE 1

FREDERICK HOUSE LAKE DAM
PLAN VIEW

8 • LOCATION OF CORE
(ie Core FH8)

Figure 2: Downstream view of Frederick House Lake Dam. This is the west face of the dam. The location of the concrete core drilled from the south gravity section by the Rock Sciences Section has been indicated.

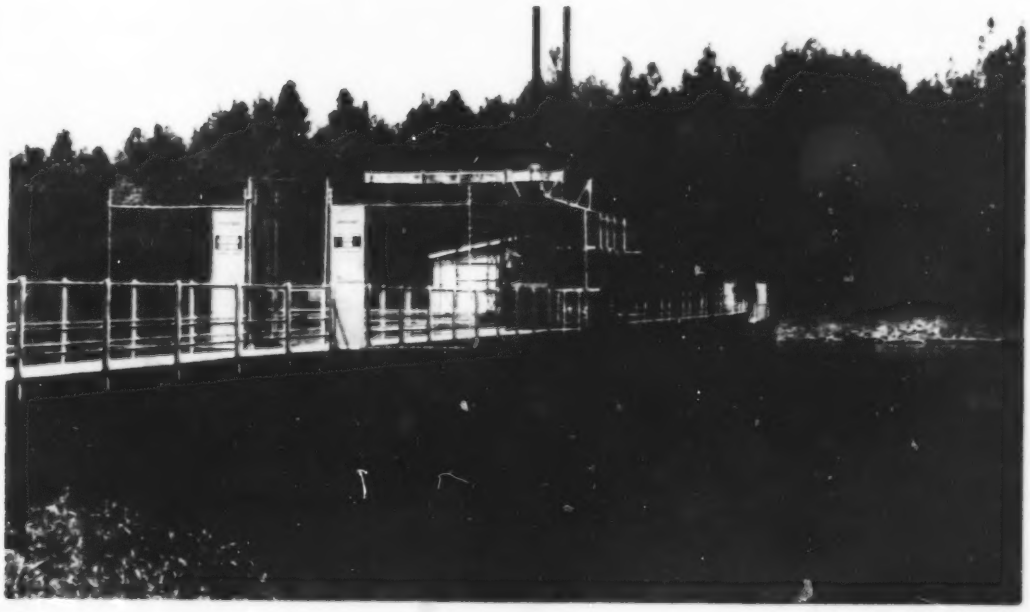


Figure 3: Upstream view of Frederick House Lake Dam as viewed from south of the dam.

FIGURE 4

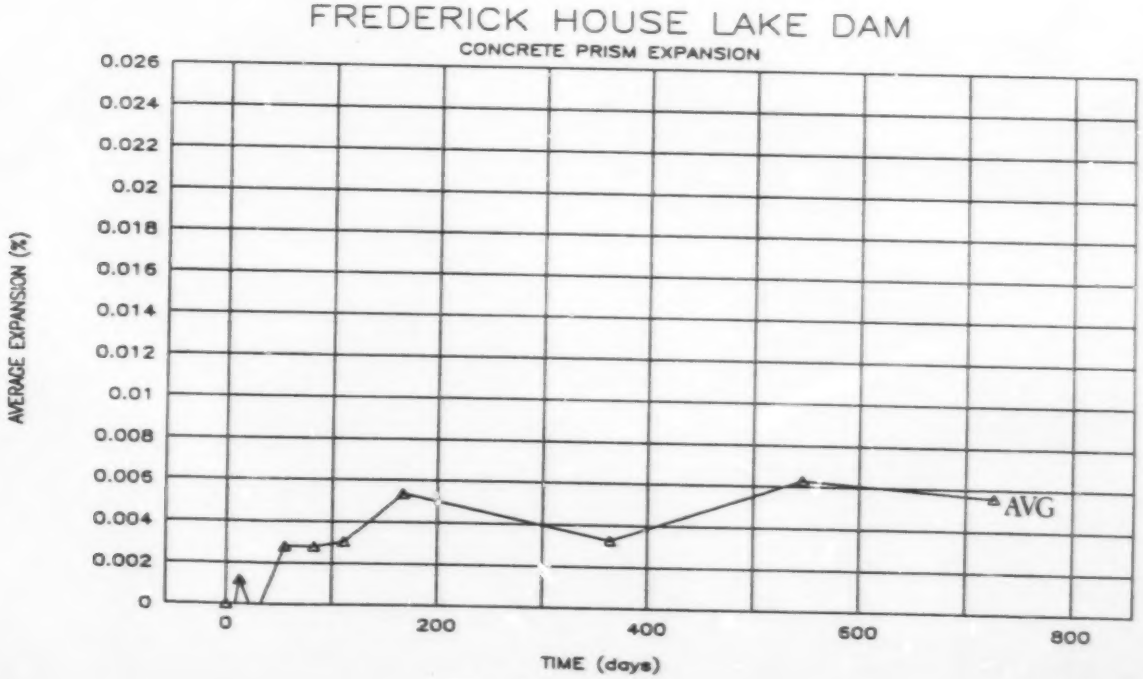
FREDERICK HOUSE LAKE DAM
EVALUATION OF CONCRETE FOR ALKALI-AGGREGATE REACTIVITY
CONCRETE PRISM EXPANSION TEST
(CAN/CSA A23.2-14A)
(23°C, 100% rh)

MIX NUMBER: 14057

DATE	TIME (days)	% EXPANSION OF SPECIMENS 1	2	3	AVG
13-Oct-89	0	0.0000	0.0000	0.0000	0.0000
19-Oct-89	6	-0.0014	0.0000	-0.0014	-0.0009
26-Oct-89	13	0.0014	0.0014	0.0007	0.0012
09-Nov-89	27	-0.0007	-0.0007	-0.0007	-0.0007
07-Dec-89	55	0.0035	0.0028	0.0021	0.0028
04-Jan-90	83	0.0028	0.0028	0.0028	0.0028
01-Feb-90	111	0.0028	0.0028	0.0035	0.0030
29-Mar-90	167	0.0056	0.0049	0.0056	0.0054
12-Oct-90	364	0.0042	0.0021	0.0035	0.0033
12-Apr-91	546	0.0070	0.0063	0.0056	0.0063
09-Oct-91	726	0.0070	0.0063	0.0035	0.0056

Materials: Fine Aggregate - S-7167 Paris Sand
Coarse Aggregate - S-7726 Frederick House Lake Dam 20 mm crushed stone
Cement - CL70180 (Alkali Content 1.00%)

Notes: Maximum expansion as recommended in CAN/CSA-A23.2 is 0.01% at 3 months or 0.025% at 1 year.
Specimens prepared from aggregates obtained from stockpiles at Frederick House Lake Dam.
Specimens stored at 23°C and 100% relative humidity.



91-239

FIGURE 5

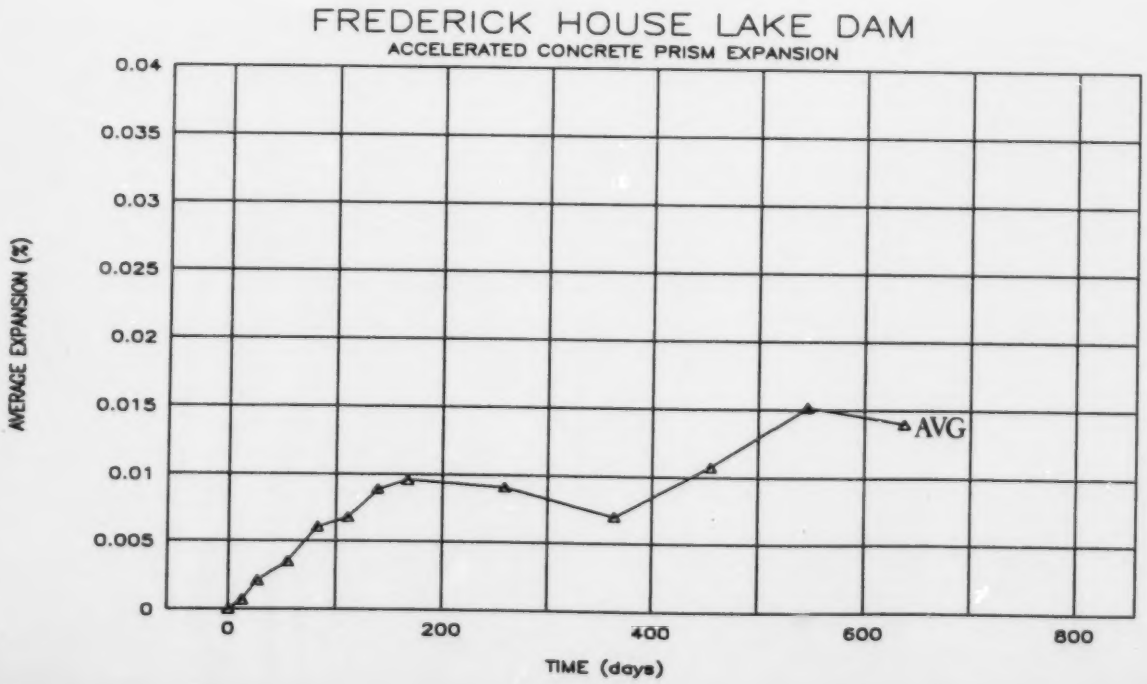
FREDERICK HOUSE LAKE DAM
EVALUATION OF CONCRETE FOR ALKALI-AGGREGATE REACTIVITY
ACCELERATED CONCRETE PRISM EXPANSION TEST
(CAN/CSA A23.2-14A)
(38°C, 100% rh)

MIX NUMBER: 14057

DATE	TIME (days)	% EXPANSION OF SPECIMENS 4	5	6	AVG
13-Oct-89	0	0.0000	0.0000	0.0000	0.0000
26-Oct-89	13	0.0000	0.0014	0.0007	0.0007
09-Nov-89	27	0.0014	0.0028	0.0021	0.0021
07-Dec-89	55	0.0028	0.0035	0.0042	0.0035
04-Jan-90	83	0.0056	0.0063	0.0063	0.0061
01-Feb-90	111	0.0063	0.0070	0.0070	0.0068
01-Mar-90	139	0.0084	0.0091	0.0091	0.0089
29-Mar-90	167	0.0091	0.0098	0.0098	0.0096
29-Jun-90	259	0.0084	0.0091	0.0098	0.0091
12-Oct-90	364	0.0063	0.0070	0.0077	0.0070
11-Jan-91	455	0.0077	0.0126	0.0119	0.0107
12-Apr-91	546	0.0126	0.0161	0.0168	0.0152
12-Jul-91	637	0.0119	0.0161	0.0140	0.0140

Materials: Fine Aggregate - S-7167 Paris Sand
Coarse Aggregate - S-7726 Frederick House Lake Dam 20 mm crushed stone
Cement - CL70180 (Alkali Content 1.00%)

Notes: Maximum expansion as recommended in CAN/CSA-A23.2 is 0.04% at 1 year.
Specimens prepared from aggregates obtained from stockpiles at Frederick House Lake Dam.
Specimens stored at 38°C and 100% relative humidity.



91-239

FIGURE 6

FREDERICK HOUSE LAKE DAM
EVALUATION OF CONCRETE FOR ALKALI-AGGREGATE REACTIVITY
LENGTH CHANGE OF CONCRETE CORES
(38°C, 100% rh)

LABORATORY IDENTIFICATION: 14083

DATE	TIME (days)	% EXPANSION OF SPECIMENS 1	2	3	AVG
27-Feb-90	0	0.000	0.000	0.000	0.000
06-Mar-90	7	0.011	0.012	0.006	0.010
14-Mar-90	15	0.012	0.006	0.007	0.008
27-Mar-90	28	0.015	0.009	0.009	0.011
24-Apr-90	56	0.017	0.012	0.009	0.013
23-May-90	85	0.018	0.013	0.009	0.013
28-Sep-90	213	0.019	0.023	0.012	0.018
29-Nov-90	275	0.020	0.021	0.011	0.017
27-Feb-91	365	0.024	0.010	-0.001	0.011
27-Aug-91	546	0.026	0.031	0.024	0.027

Notes:

Specimens prepared from the concrete core (Core BH1) drilled from the south gravity section of Frederick House Lake Dam.

Specimen 1 obtained from a depth of 5.5 to 6.1 m in the core.
Specimen 2 obtained from a depth of 7.4 to 10.8 m in the core.
Specimen 3 obtained from a depth of 13.5 to 18.4 m in the core.

Specimens stored at 38°C and 100% relative humidity.

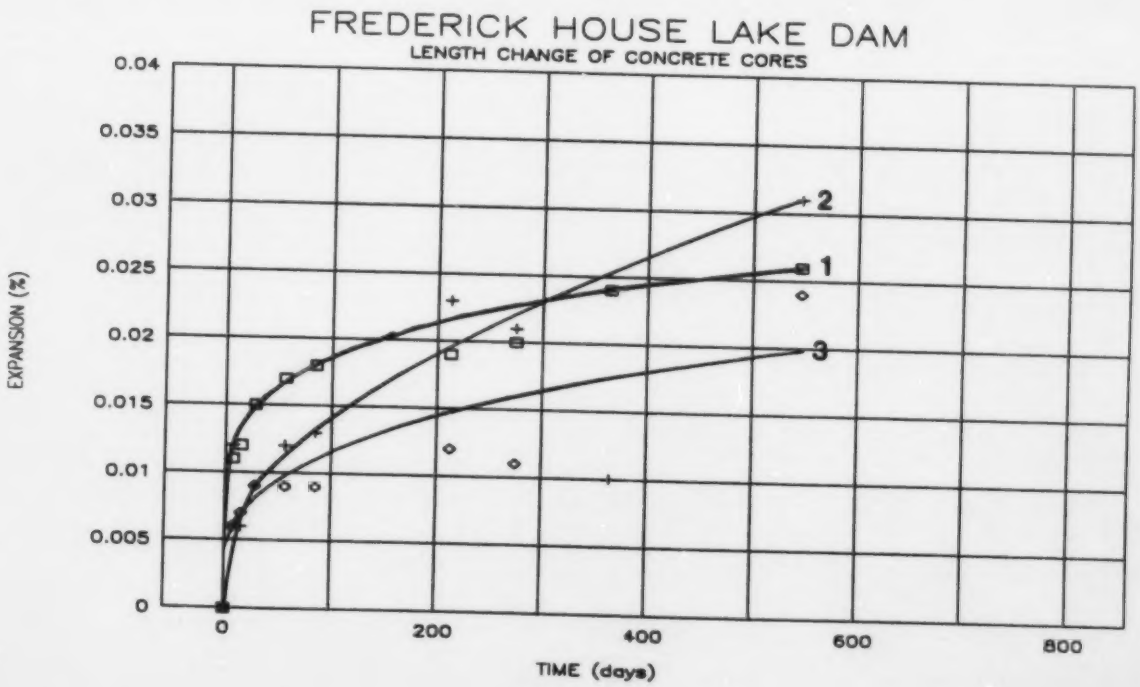


FIGURE 7

FREDERICK HOUSE LAKE DAM
EVALUATION OF CONCRETE FOR ALKALI-AGGREGATE REACTIVITY
LENGTH AND WEIGHT CHANGE OF CONCRETE CORE SPECIMENS

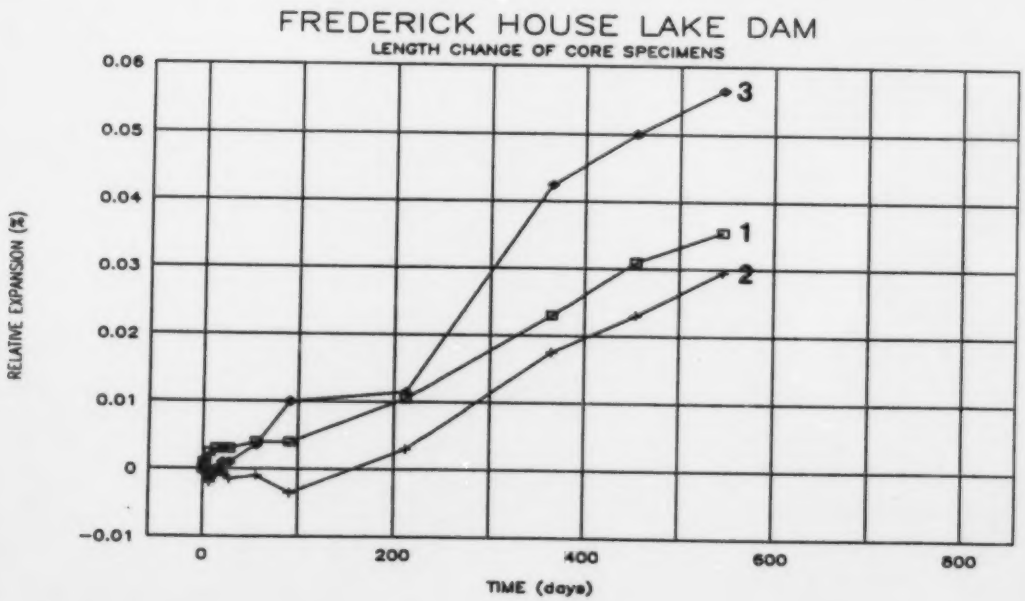
Section A - stored in lime water at 23°C
Section B - stored in 1M NaOH solution at 23°C

LABORATORY IDENTIFICATION: 14083

DATE	TIME (days)	% EXPANSION OF SPECIMENS					
		1		2		3	
		A	B	A	B	A	B
27-Feb-90	0	0.000	0.000	0.000	0.000	0.000	0.000
28-Feb-90	1	0.002	0.003	0.003	0.002	0.003	0.003
02-Mar-90	3	0.002	0.003	0.004	0.004	0.004	0.004
06-Mar-90	7	-0.002	0.001	0.005	0.003	0.004	0.003
13-Mar-90	14	-0.005	-0.002	0.005	0.004	0.004	0.004
20-Mar-90	21	-0.006	-0.003	0.004	0.004	0.005	0.006
27-Mar-90	28	-0.005	-0.002	0.005	0.004	0.005	0.006
24-Apr-90	56	-0.007	-0.003	0.007	0.006	0.007	0.010
29-May-90	91	-0.005	-0.001	0.008	0.005	0.005	0.015
27-Sep-90	212	-0.006	0.005	0.005	0.008	0.005	0.016
27-Feb-91	365	-0.004	0.020	0.006	0.024	0.006	0.049
27-May-91	454	-0.006	0.025	0.005	0.028	0.005	0.055
27-Aug-91	546	-0.006	0.030	0.004	0.034	0.005	0.061

Notes: Specimens prepared from the concrete core (Core BH1) drilled from the south gravity sections of Frederick House Lake Dam.

Specimen 1 obtained from a depth of 5.5 to 6.1 m in the core.
Specimen 2 obtained from a depth of 7.4 to 10.8 m in the core.
Specimen 3 obtained from a depth of 13.5 to 18.4 m in the core.



Plotted above is the expansion of specimens stored in the NaOH solution less the expansion of the specimens stored in lime water.

FIGURE 8

FREDERICK HOUSE LAKE DAM
EVALUATION OF CONCRETE FOR ALKALI-AGGREGATE REACTIVITY
LENGTH AND WEIGHT CHANGE OF CONCRETE CORE SPECIMENS

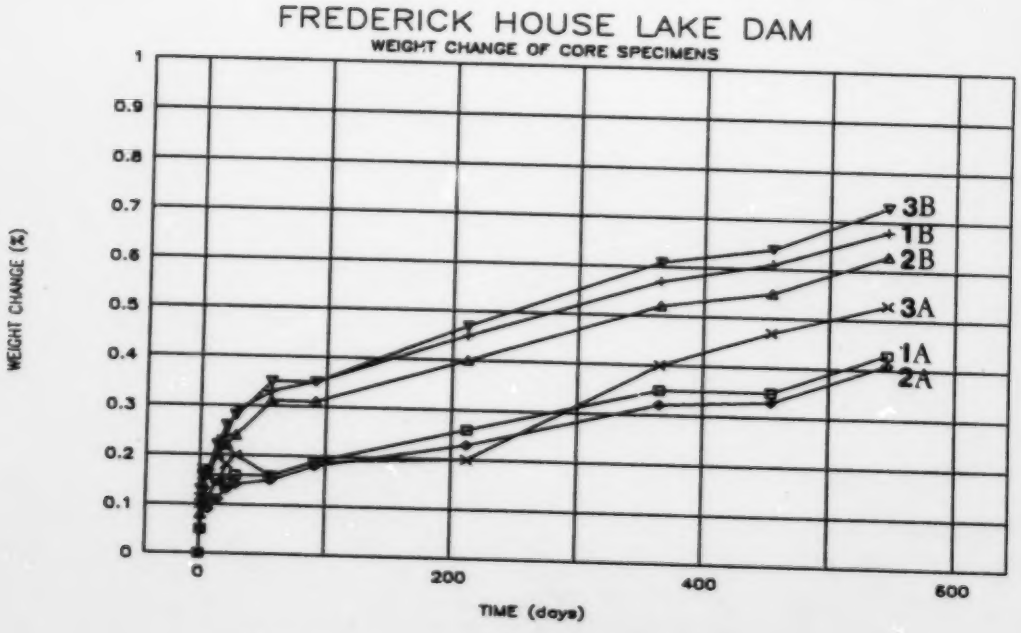
Section A - stored in lime water at 23°C
Section B - stored in 1M NaOH solution at 23°C

LABORATORY IDENTIFICATION: 14083

DATE	TIME (days)	% WEIGHT CHANGE OF SPECIMENS					
		1		2		3	
		A	B	A	B	A	B
27-Feb-90	0	0.00	0.00	0.00	0.00	0.00	0.00
28-Feb-90	1	0.05	0.12	0.05	0.06	0.10	0.13
02-Mar-90	3	0.11	0.15	0.13	0.14	0.17	0.16
06-Mar-90	7	0.11	0.17	0.09	0.16	0.16	0.17
13-Mar-90	14	0.15	0.23	0.11	0.20	0.14	0.22
20-Mar-90	21	0.15	0.24	0.13	0.22	0.18	0.26
27-Mar-90	28	0.16	0.29	0.14	0.24	0.20	0.28
24-Apr-90	56	0.16	0.33	0.15	0.31	0.16	0.35
29-May-90	91	0.19	0.35	0.18	0.31	0.19	0.35
27-Sep-90	212	0.26	0.45	0.23	0.40	0.20	0.47
27-Feb-91	365	0.35	0.57	0.32	0.52	0.40	0.61
27-May-91	454	0.35	0.61	0.33	0.55	0.47	0.64
27-Aug-91	546	0.43	0.68	0.41	0.63	0.53	0.73

Notes: Specimens prepared from the concrete core (Core BH1) drilled from the south gravity sections of Frederick House Lake Dam.

Specimen 1 obtained from a depth of 5.5 to 6.1 m in the core.
Specimen 2 obtained from a depth of 7.4 to 10.8 m in the core.
Specimen 3 obtained from a depth of 13.5 to 18.4 m in the core.



Plotted above is the weight change of each specimen.

APPENDIX A

FREDERICK HOUSE LAKE DAM
REVIEW OF HISTORICAL INFORMATION

Item 1 - Examination of two rock samples by J.E. Thomson of the University of Toronto.

Item 2 - Research Division Report S84-41-H "Examination of Concrete Samples From Frederick House Lake Dam on Abitibi River", (This title appears to be in error since the dam is actually located on the Frederick House River).

Item 3 - Excerpts from Research Division Report 90-210-K on testing of aggregates from Frederick House Lake Dam.

J. ELLIS THOMSON
MINING BUILDING
UNIVERSITY OF TORONTO
TORONTO 5, CANADA

Report on Thin Sections of Rocks for Hydro-Electric Power Commission, Strachan Ave., Toronto, Apr.2/37

No.1 - is a fine-grained diabasic rock composed chiefly of fine laths of altered plagioclase and of chlorite and carbonate, but containing also minor quantities of magnetite and interstitial quartz. There has been considerable alteration of plagioclase to carbonate. This is an altered diabase.

No.2 - is a porphyritic rock with large to medium-sized phenocrysts of altered plagioclase and to a lesser extent of fresh quartz and of aggregates of chlorite and rutile, in a dense ground-mass composed chiefly of quartz, altered feldspar, white mica, and chlorite, but with minor quantities of apatite, titanite, and ilmenite. There has been considerable alteration of feldspars to white mica and of ilmenite to titanite or rutile. This is an altered quartz porphyrite.

Remarks - Although both these rocks are somewhat altered, their cohesive properties should be good and there seems no reason why they should not serve as excellent material for concrete.

91600
new 82-10

Mr. G.S. Kelley

ontario hydro
research division

To Mr. O. Bernaus
Supervising Engineer
Civil Works Department
Thermal & Hydraulic Generation
A5H6

Attn: Mr. D. Beck

FOR ONTARIO HYDRO USE ONLY
Unless release outside is authorized by a director.

EXAMINATION OF CONCRETE SAMPLES FROM
FEDERICK HOUSE LAKE DAM
ON ABITIBI RIVER

P.K. Mukherjee

1.0 INTRODUCTION

A few chunks of concrete, believed to be from the body of the above dam (exact location unknown), were received for examination. It is reported that the dam is about 45 years old and is showing signs of distress (ie, cracking, squeezing of joints). The purpose of the examination is to determine and comment on whether or not alkali aggregate reactivity is a possible cause for the distress.

2.0 EXAMINATION

(a) A section of the sample was saw-cut and prepared for microscopic examination. The sample indicates a well compacted concrete and mainly consists of crushed stone, 20 mm maximum size, and natural sand. The amount of crushed stone appears to be somewhat lower than normal. Several localized microcracks through aggregate particles, some of them extending into the surrounding cement paste, were noticed. A staining test on a freshly broken section showed surface carbonation to a depth of about 15 mm, which is not uncommon for an old concrete.

(b) The air-void system (AVS) was determined by ASTM-C457 Modified Point Count Method with the following results:

Air content = 4.2%

Spacing factor = 0.643 mm

job	file	date	report no.
740642-001-902	842.512(P)	December 12, 1984	S84-41-H

Specific surface = 8.69 mm^{-1}

Cement paste content = 31.7%

Note: A good quality freeze-thaw resistant concrete should have an adequate amount of air (4 to 6%) with a spacing factor not exceeding 0.20 mm and a specific surface of at least 23.6 mm^{-1}.

(c) A preliminary petrographic examination of the sample was carried out by Mr. R. Koopmans of the Rock Sciences Section of the Civil Research Department. The presence of alkali-silica reactivity was reported/1/ and the suspect aggregates were identified as greywacke and/or argillite. The microcracks noticed in the sample are associated with the reactivity.

3.0 REMARKS

The sample indicates a well compacted concrete, and the aggregates show good bond with the paste. However, the air-void system is not adequate for protection against freeze-thaw (F/T) exposure under saturated condition. The alkali reactive aggregates in the presence of moisture will cause expansion and cracking. It would therefore appear that the distress noticed in the dam is possibly a combination of the above two factors (ie, F/T and alkali-aggregate reaction).

4.0 RECOMMENDATION

A further detailed examination of the dam, as well as analyses of samples obtained from selected locations, is recommended. The data thus obtained will provide information to determine the extent of the problem and to evaluate the need for remedial measures.

Approved:

T.W. Klym
Manager
Civil Research Department

Submitted:

P.K. Mukherjee
Engineer
Concrete Technology Section

PKM:SEH

/1/ Internal memo from R. Koopmans to P.K. Mukherjee, dated Novebber 9, 1984.

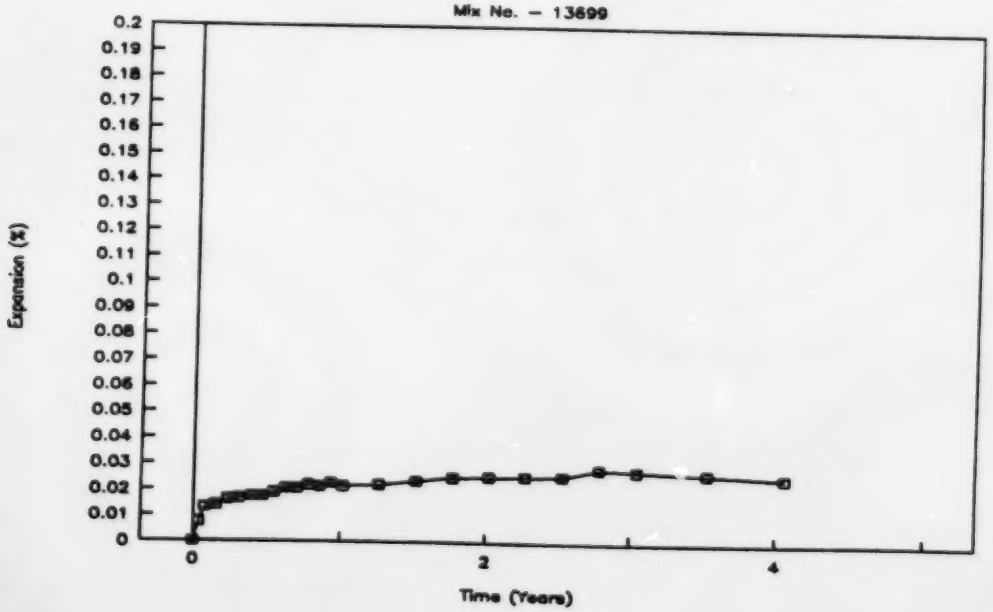
ITEM 3 POTENTIAL ALKALI REACTIVITY OF CEMENT-AGGREGATE COMBINATIONS
(MORTAR-BAR METHOD)
ASTM C 227

Mix No. : 13699
No. of Specimens : 4
Project : FREDERICK HOUSE
Date Cast : 26-Sep-85
Age (as of Jan 1/90) : 4 years
Remarks : Specimens stored in Pail 22 (with wicks)

Aggregate: S-1626 ERAUNHANDS SAND
Cement: CL69317 LAB. STD. (ALK 1.17%)

TEST DATA

Date	Age (Months)	Avg Exp (%)
27-Sep-85	0.0	0.000
10-Oct-85	0.4	0.007
24-Oct-85	1	0.013
21-Nov-85	2	0.014
19-Dec-85	3	0.016
16-Jan-86	4	0.017
14-Feb-86	5	0.018
13-Mar-86	6	0.018
10-Apr-86	7	0.019
08-May-86	7	0.021
05-Jun-86	8	0.021
03-Jul-86	9	0.022
31-Jul-86	10	0.021
28-Aug-86	11	0.023
26-Sep-86	12	0.021
24-Dec-86	15	0.022
26-Mar-87	18	0.023
26-Jun-87	21	0.025
25-Sep-87	24	0.025
24-Dec-87	27	0.026
25-Mar-88	30	0.026
24-Jun-88	33	0.029
27-Sep-88	37	0.028
23-Mar-89	42	0.027
26-Sep-89	49	0.026



91-239

POTENTIAL ALKALI REACTIVITY OF CEMENT-AGGREGATE COMBINATIONS
(MORTAR-BAR METHOD)
ASTM C 227

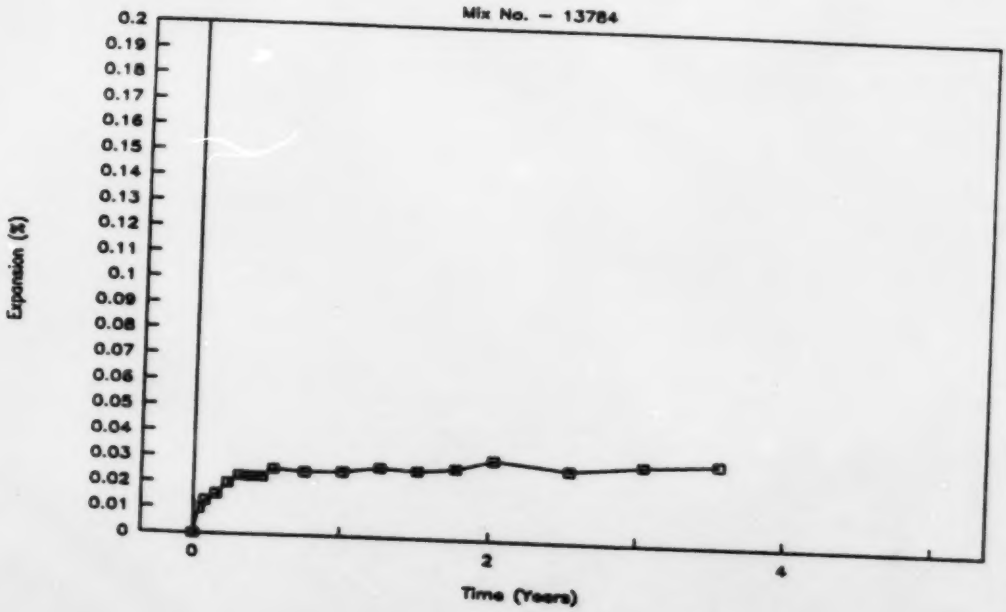
Mix No. : 13784
No. of Specimens : 4
Project : FREDERICK HOUSE
Date Cast : 07-Aug-86
Age (as of Jan 1/90) : 3 years
Remarks : Specimens stored in Pail 25 (with wicks)

Aggregate: S-1622 NELLIS LAKE CR GR
Cement: CL 69317 LAB. STD. (ALK 1.17%)

TEST DATA

Date	Age (Months)	Avg Exp (%)
08-Aug-86	0.0	0.000
21-Aug-86	0.4	0.010
04-Sep-86	1	0.013
02-Oct-86	2	0.016
30-Oct-86	3	0.020
27-Nov-86	4	0.023
24-Dec-86	5	0.023
22-Jan-87	6	0.023
19-Feb-87	7	0.026
07-May-87	9	0.025
07-Aug-87	12	0.025
06-Nov-87	15	0.027
05-Feb-88	18	0.026
06-May-88	21	0.028
05-Aug-88	24	0.031
07-Feb-89	30	0.028
09-Aug-89	37	0.031
09-Feb-90	43	0.032

Date	Age (Months)	Avg Exp (%)



91-239

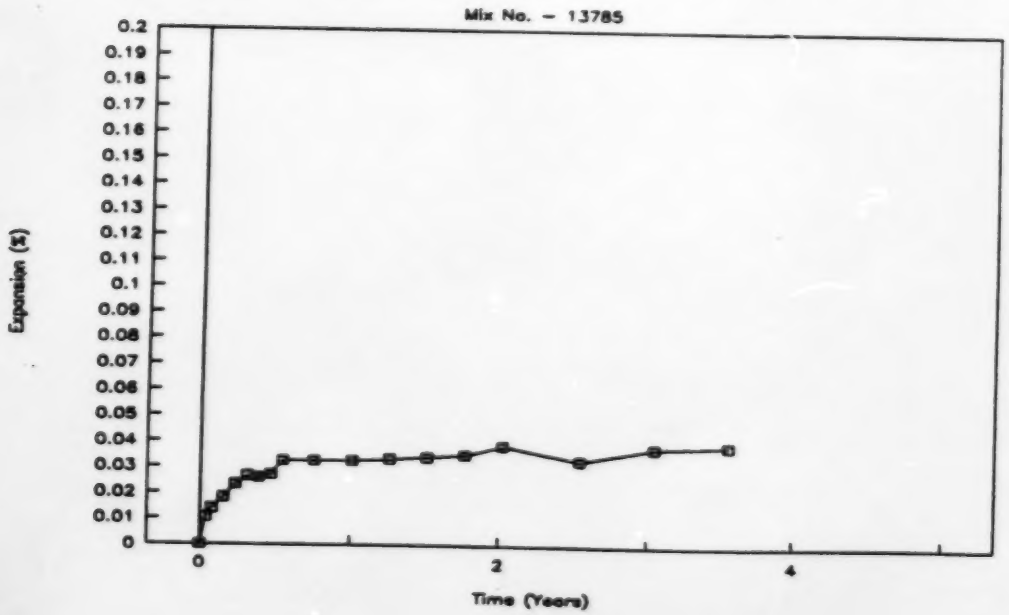
POTENTIAL ALKALI REACTIVITY OF CEMENT-AGGREGATE COMBINATIONS
(MORTAR-BAR METHOD)
ASTM C 227

Mix No. : 13785
No. of Specimens : 4
Project : FREDERICK HOUSE
Date Cast : 07-Aug-86
Age (as of Jan 1/90) : 3 years
Remarks : Specimens stored in Pail 25 (with wicks)

Aggregate: S-1622 NELLIS LAKE PASS NO4
Cement: CL 69317 LAB. STD. (ALK 1.17%)

TEST DATA

Date	Age (Months)	Avg Exp (%)	Date	Age (Months)	Avg Exp (%)
08-Aug-86	0.0	0.000			
21-Aug-86	0.4	0.011			
04-Sep-86	1	0.014			
02-Oct-86	2	0.018			
30-Oct-86	3	0.023			
27-Nov-86	4	0.027			
24-Dec-86	5	0.026			
22-Jan-87	6	0.027			
19-Feb-87	7	0.032			
07-May-87	9	0.032			
07-Aug-87	12	0.032			
06-Nov-87	15	0.033			
05-Feb-88	18	0.034			
06-May-88	21	0.035			
05-Aug-88	24	0.039			
07-Feb-89	30	0.033			
09-Aug-89	37	0.038			
09-Feb-90	43	0.039			



91-239

APPENDIX B

FREDERICK HOUSE LAKE DAM
CONCRETE CORE LOG

APPENDIX B

FREDERICK HOUSE LAKE DAM
CONCRETE CORE LOG

CONCRETE CORING - 1989

In 1989, a core was drilled from the south gravity section by the Rock Sciences Section, Civil Research Department, as part of an investigation into internal stresses in the dam. The results of the investigation are given in Research Division Report 90-213-K. From this core, sections were selected and shipped to the Research Division laboratories. The sections of core received by the Concrete Technology Section are listed below.

Core No.	Location in Core From - To	Remark
Core BH1 (South Gravity Section)	5.50 - 6.10 m	
	7.40 - 7.85 m	
	10.15 - 10.40 m	
	10.40 - 10.80 m	
	13.50 - 13.90 m	- two sections of core
	15.10 - 15.70 m	- two sections of core
	17.70 - 18.45 m	

General Notes

- The sections of core appeared in good condition and had a nominal diameter of 85 mm.
- The coarse aggregate consisted of crushed rock and was well distributed, but there appeared to be a high proportion of mortar.
- The nominal maximum size of the aggregate was 28 mm.

CONCRETE CORING - 1991

From June 12 to 13, 1991, concrete cores were drilled from several locations at the dam. The coring was carried out by the Concrete Technology Section, Civil Research Department. The core locations and description of the cores are given below. Core locations are shown in Figure 1 in the main body of this report.

Core No.	Location in Core From - To	Core Section	Remarks
Core FH1 (North Gravity Section)	0 - 0.28 m 0.28 - 0.60 m	FH1-1 FH1-2	- top 40 mm of core exhibited minor cracking
Core FH2 (Deck Slab)	0 - 0.30 m	FH2-1	- deck slab 0.40 m thick
Core FH3 (Deck Slab)	0 - 0.30 m	FH3-1	- deck slab 0.40 m thick - top 30 mm of core exhibited minor cracking
Core FH4 (Spillway Pier)	0 - 0.33 m 0.33 - 0.57 m	FH4-1 FH4-2	- top 40 mm of core exhibited minor cracking - non-deformed steel bar, 13 mm diameter, at 0.54 m
Core FH5 (Deck Slab)	0 - 0.28 m	FH5-1	- deck slab 0.40 m thick
Core FH6 (Deck Slab)	0 - 0.32 m	FH6-1	- deck slab 0.40 m thick
Core FH7 (Deck Slab)	0 - 0.31 m	FH7-1	- deck slab 0.40 m thick - top 30 mm of core exhibited minor cracking
Core FH8 (Deck Slab)	0 - 0.34 m	FH8-1	- deck slab 0.40 m thick
Core FH9 (South Gravity Section)	0 - 0.30 m 0.30 - 0.61 m	FH9-1 FH9-2	- non-deformed steel bar, 13 mm diameter, at 0.34 m
Core FH10 (South Gravity Section)	0 - 0.30 m 0.30 - 0.65 m	FH10-1 FH10-2	
Core FH11 (South Gravity Section)	0 - 0.31 m 0.31 - 0.63 m	FH11-1 FH11-2	- vertical crack extends to depth of 0.34 m - non-deformed steel bar, 13 mm diameter, at 0.36 m

General Notes

- The sections of core appeared in good condition and are shown in Figures B1 and B2.
- The cores were drilled vertically from the dam and had a nominal diameter of 95 mm.
- The aggregate was well distributed and had a nominal maximum size of 28 mm.
- The coarse aggregate appeared to originate from crushed rock.
- Random cracking was observed in the gravity sections and spillway piers and deck. In the gravity section and piers, the cracks were widely spaced, and based on the width, appeared to extend below the surface (in Core FH11, a crack was found to extend to a depth of 0.34 m). In the deck, the cracks were closely spaced and appeared to be confined to the top 0.03 m of the concrete. The extent of cracking in the deck sections varied, and has been classified as minor, moderate, or extensive for the description of the core locations given below.
- The core locations are shown in Figure 1 and described below:

Core FH1	-	drilled from the north gravity section, 0.57 m from the upstream face of the dam
	-	concrete in the north gravity section exhibited random cracking
Core FH2	-	drilled from Deck Slab 1 (slabs numbered from north to south), 0.26 m from the downstream edge of the deck
	-	concrete in the vicinity of the core location exhibited minor surface cracking
Core FH3	-	drilled from Deck Slab 4, 1.50 m from the downstream edge of the deck
	-	concrete in the vicinity of the core location exhibited moderate surface cracking
Core FH4	-	drilled from the pier between Deck Slabs 4 and 5, 1.42 m from the downstream edge of the deck
	-	concrete in the vicinity of the core location exhibited moderate surface cracking
Core FH5	-	drilled from Deck Slab 5, 2.60 m from the downstream edge of the deck
	-	concrete in the vicinity of the core location exhibited extensive surface cracking
Core FH6	-	drilled from Deck Slab 6, 0.50 m from the upstream edge of the deck
	-	concrete in the vicinity of the core location exhibited minor surface cracking
Core FH7	-	drilled from Deck Slab 8, 0.80 m from the downstream edge of the deck
	-	concrete in the vicinity of the core location exhibited extensive surface cracking
Core FH8	-	drilled from Deck Slab 9, 1.01 m from the downstream edge of the deck
	-	concrete in the vicinity of the core location exhibited extensive surface cracking
Core FH9	-	drilled from the south gravity section, 3.85 m south of the spillway and 0.86 m from the upstream face
	-	concrete in the south gravity section exhibited random cracking
Core FH10	-	drilled from the south gravity section, approximately 20 m south of the spillway and 0.75 m from the upstream face
	-	concrete in the south gravity section exhibited random cracking
Core FH11	-	drilled from the south gravity section, approximately 27 m from the spillway and 0.83 m from the upstream face
	-	concrete in the south gravity section exhibited random cracking

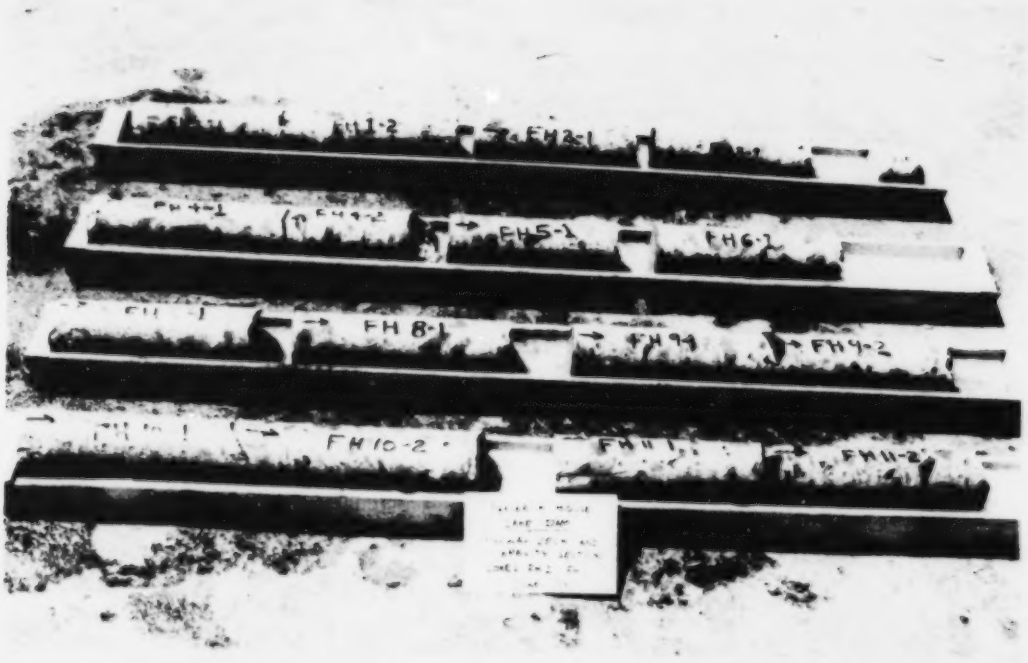


Figure B1: Cores FH1 to FH11 drilled from various locations at Frederick House Lake Dam.

Figure B2: Detailed view of cores drilled from a pier (Core FH4), the deck (Cores FH5, FH7 and FH8) and the south gravity section (Core FH10).

APPENDIX C

FREDERICK HOUSE LAKE DAM
PETROGRAPHIC EXAMINATION OF CONCRETE CORE

(The core was obtained in 1989 from the south gravity section.)

Mr. E.J. McColm

ontario hydro
research division

To: Dr. T.W. Klym
Manager
Civil Research Department

Attn: Mr. E.J. McColm

FREDERICK HOUSE LAKE DAM
PETROGRAPHIC EXAMINATION OF CONCRETE CORE

M.F. Everitt

1.0 INTRODUCTION

A petrographic examination of core sections was undertaken as part of an investigation to determine whether any alkali-aggregate reaction has taken place in the concrete of the Frederick House Lake Dam. The core sections were selected from Borehole 1*, drilled vertically through the south gravity section of the dam by the Rock Sciences Section, Civil Research Department. The examination included a visual assessment of the cores for evidence of alkali-aggregate reactions and other signs of deterioration. Polished specimens and thin sections were also prepared and examined microscopically to assist in evaluating the status of alkali-aggregate reaction in the concrete and identifying the rock types comprising the aggregates.

2.0 PETROGRAPHIC EXAMINATION

Three core sections, at depths of 5.9, 10.4 and 17.8 m in Borehole 1, were examined. Concrete from the south gravity section of the dam has undergone approximately 53 years of exposure in an outdoor environment of high relative humidity. A detailed petrographic examination of specimens from these core sections is included in Attachments 1 to 3. Except for minor variations with depth, the concrete specimens are petrographically similar and can be summarized as a group.

---

* See Research Division Report No. 90-213-K for location of Borehole 1.

job	file	date	report no.
44-227-481	842.5 FRE	January 16, 1991	S90-47-K

2.1 Coarse and Fine Aggregates

Construction records for this structure state that the coarse aggregate was obtained from bedrock excavated at the dam site. The coarse aggregate consists of 95% - 100% metasedimentary and metavolcanic migmatites. Most of the rocks have undergone moderate to intensive alteration. Principally, ferromagnesian minerals have been replaced by chlorite and/or carbonate, while clay minerals or white mica have replaced the alkali feldspars. Unaltered granite gneiss and rhyolite make up the remaining 0%-5% of the coarse aggregate.

The fine aggregate was obtained from the Ministry of Transportation, Ontario, (MTO) Pit P2322 - 17, located on Lot 12, Concession 5, in Calvert Township. At the time of construction, this pit was situated on Crown Land. The fine aggregate is composed predominantly of granite gneiss and associated minerals - quartz and feldspar, with lesser amounts of greywacke, volcanic and carbonate rock fragments. Minor amounts of chert, 1%-2% by volume, are also present.

2.2 Cement Paste

All core sections examined had a dull, light grey, non-air-entrained cement paste. Entrapped air voids tended to be irregularly shaped and represented 1%-3% of the total volume.

Occasional, non-continuous cracks were observed in all specimens. These cracks generally either terminated at, or extended around, aggregate particles. A few cracks extended through aggregate particles. Cracking within the deepest section (17.8 m) tended to be tight fractures (See Figure 1).

2.3 Alkali-Aggregate Reactivity

Many of the coarse aggregate particles were cracked or fractured. Most of these fractures appeared to be relict structures, such as original bedding planes or flow banding, and did not extend into the cement paste. A few of the cracks were filled with alkali-silica gel, which continued into the cement paste (See Figure 2).

Several sand-sized (<5 mm) chert particles, gelatinized to varying degrees, were cracked, with the cracks extending into the cement paste. (See Figure 3).

Reaction rims around many of the coarse aggregate particles were noted, especially with the deepest section (17.8 m). The rims consisted of a layer of ettringite and alkali-silica gel (<0.2 mm wide), which graded to a carbonated cement paste and finally to a non-carbonated cement paste (See Figure 4).

3.0 DISCUSSION

Evidence of alkali-aggregate reactions was observed in all of the core sections examined. The extent of these reactions was minor and limited to a few alkali-silica gel filled cracks associated with metasedimentary and metavolcanic migmatite coarse aggregates and several sand-sized chert particles. These chert particles have been gelatinized to varying degrees, depending on the extent to which reaction with the cement alkalies has progressed. It should be noted that these observations apply to the concrete in the vicinity of Borehole 1, and cannot be extrapolated across the entire dam without further study.

Approved by:

G.S. Kellay
Supervising Engineer
Concrete Technology Section

MFE:td

Prepared by:

M.F. Everitt
Petrographer
Concrete Technology Section

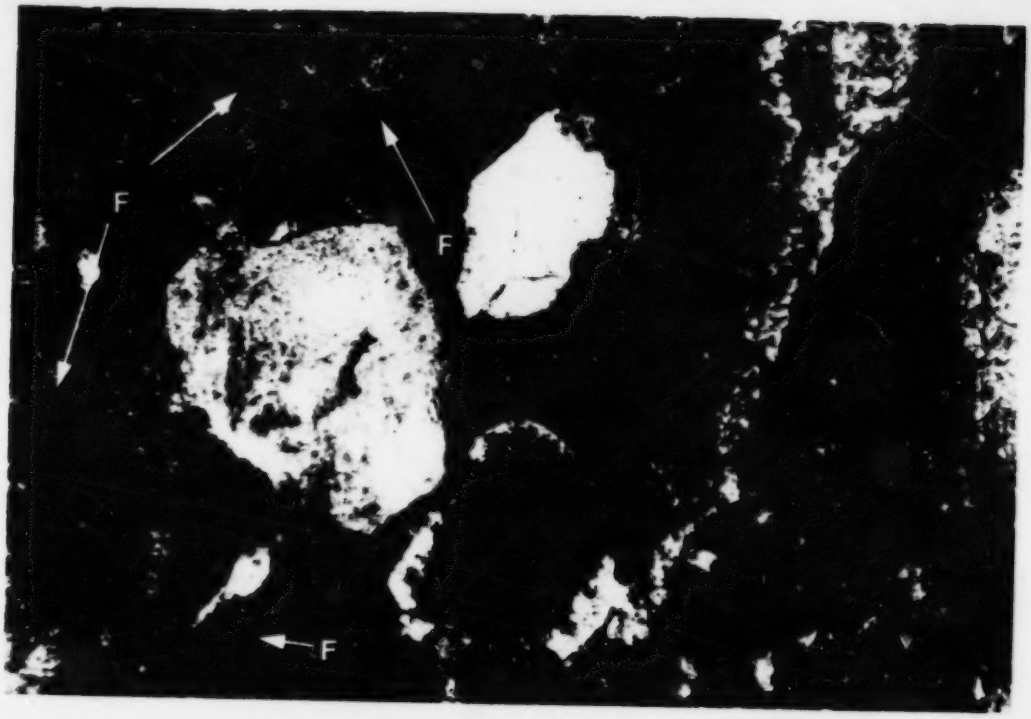


Figure 1: Frederick House Lake Dam: Tight fractures (F) within the cement paste. (LTS 64, Analyzer-out, Mag. 32X)

Figure 2: Frederick House Lake Dam: Crack (C) filled with gel (G) originating in coarse aggregate particle (A) and extending into the cement paste (P). (LTS 63, Analyzer - out, Mag. 32X).

Figure 3: Frederick House Lake Dam: Gelatinized chert particle (Ch) with cracks (C), filled with gel (G), extending into the cement paste (P) and through fine aggregate particles (f). (LTS 62, Analyzer - out, Mag. 32X)

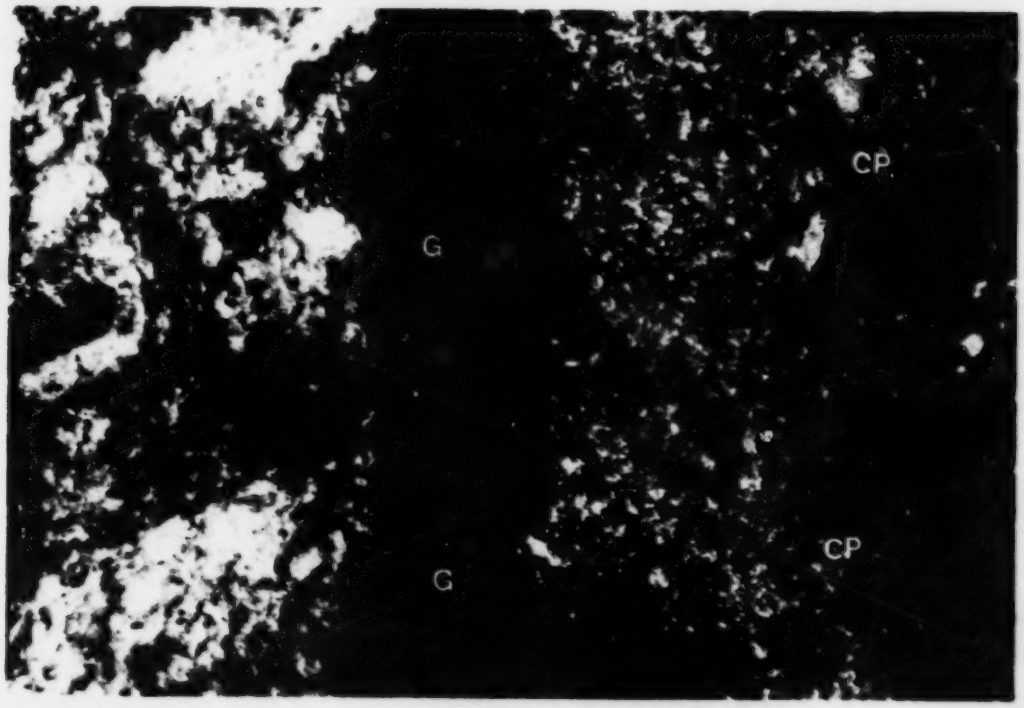


Figure 4: Frederick House Lake Dam: Surface of aggregate particle (A) covered with a layer of ettringite and gel (G), grading outwards to carbonated cement paste (CP). (LTS 64, Analyzer and λ plate-in, Mag.64X)

ATTACHMENTS 1 to 3

Frederick House Lake Dam
Petrographic Examination of Hardened Concrete

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE

Project : Frederick House Lake Dam
Region : Northeastern
Area : Timmins
Structure : Frederick House Lake Dam

Job No. : 44-227
File No. : 842.5 FRE
Report No. : SN90-1-K
Date Issued : December 12, 1990

Sample Type : **Core** [X] **Cylinder** [ ] **Chunk** [ ]

Sample Description : Section (depth=5.9 m, nominal 85 mm diameter) from Borehole 1 drille vertically through gravity section . The concrete has undergone approximately 53 years of expo in an environment of high relative humidity.

Sample Preparation : **Freshly broken surface** [ ] **Weathered surface** [ ] **Polished face** [X] **Thin Section** [X] / **No.** LTS 62

CONCRETE

Hit with hammer	:	**Ring** [X]	**Dull** [ ]		
Break with fingers	:	**Particles not dislodged** [X]	**Powdery** [ ]	**Friable** [ ]	
During sawing	:	**Clean cut** [X]	**Breaks easily** [ ]		
Cement / coarse aggregate bond	:	**Good** [X]	**Partial** [ ]	**Poor** [ ]	
Cement / fine aggregate bond	:	**Good** [X]	**Partial** [ ]	**Poor** [ ]	
Presence of honeycombing	:	**Not observed** [X]	**Minor** [ ]	**Extensive** [ ]	

COARSE AGGREGATE

Source : Bedrock from site excavations.
% of total volume : 30-35% **Visual estimate** [X] **Point count** [ ]
Material type : **Gravel** [ ] **Quarried** [X] **Mixture** [ ] **Other -**
Shape : **Rounded** [ ] **Partly crushed** [ ] **100 % Crushed** [X]
Distribution : **Even** [ ] **Uneven** [X] **Chaotic** [ ]
Nominal size : 28 (mm)
Maximum size : 28 (mm)
Preferred orientation : **Present** [ ] **Not observed** [X]

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS / GEL / FRACTURES	REMARKS
Metavolcanic and metasedimentary migmatites.	95-97	Some particles are fractured but most fractures do not extend into the cement paste.Darkening of the cement paste around some particles may indicate the presence of alkali-silica gel. Some fractures are contained within aggregate particles.	Moderately to extensively altered. Ferromagnesian minerals have been replaced by chlorite and/or carbonate.White mica and clay minerals have replaced the alkali feldspars.
Granite gneiss	3-5		

FINE AGGREGATE

Source : MTO Map Inv. No. I02-015. MTO pit P2322-17,Lot 12, Conc. 5,Calve Twp.
% of total volume : 50-55 % **Visual estimate** [X] **Point count** [ ]
Material type : **Natural** [X] **Manufactured** [ ] **Mixture** [ ] **Other -**
Shape : **Rounded** [ ] **Subrounded** [X] **Subangular** [X] **Angular** [ ]
Distribution : **Even** [X] **Uneven** [ ] **Chaotic** [ ]
Preferred orientation : **Present** [ ] **Not observed** [X]

cont.

CEMENT MATRIX

% of total volume :	20–25 %	Visual estimate [X]		Point count [ ]	
Appearance of broken surface :		Subtranslucent [X]		Dull [ ]	Chalky [ ]
Colour :	Grey [ ]	Light Grey [X]	White [ ]	Brown [ ]	Other -
Colour distribution :	Even [X]	Mottled [ ]		Gradational [ ]	
Bleeding :	Extensive [ ]	Minor [ ]		Not observed [X]	
Carbonation :	Surficial only [X]	Along fractures [ ]		Partial [ ]	Total [ ]
Slag cement :	Observed [ ]	Not observed [X]			
Fly ash :	Observed [ ]	Not observed [X]			

VOIDS

% of total volume :	1–3 %	Visual estimate [X]		Point count [ ]	
Distribution :	Even [ ]	Uneven [X]		Clustered [ ]	
Shape :	Spherical [ ]	Nonspherical [ ]		Ellipsoidal [ ]	Irregular [X]
Entrained air :	Air-entrained [ ]	Non-air-entrained [X]			
Interior lustre :	Dull [X]	Shining [ ]			
Interior condition :	Empty [X]	Lined [X]		Partly filled [ ]	Totally filled [ ]
% Voids with mineralization :	Most [ ]	About half [ ]		Few [X]	None [ ]
Mineralization :	Alkali-silica gel [ ]	Ettringite [X]		Portlandite [ ]	Calcium carbonate [ ]

CRACKS

Amount : Extensive [ ] Occasional [X] None [ ]

Continuity and Distribution: Short (less than 5 mm), discontinuous cracks. Most cracks within aggregate particles do not extend out into the cement paste.

Orientation :	Vertical [ ]	Horizontal [ ]	Random [X]	
Location :	Through aggregate particles [X]	Around aggregate particles [X]		
Width (mm) :	Range 0.0 to 0.1	Average < 0.1		
% filled :	20–30 %			
Filling material :	Alkali-silica gel [X]	Ettringite [ ]	Portlandite [ ]	
	Calcium carbonate [ ]	Other -		
Associated with embedded items :	Yes [ ]	No [X]		

EMBEDDED ITEMS Yes [ ] No [X]

Description :
Condition : Clean [ ] Corroded [ ] Decayed [ ]
Size (mm) :
Location / Orientation :
Other :

GENERAL COMMENTS

A few voids are lined with microscopic needles of ettringite. Gel filled cracks are associated with some sand-sized chert particles, as well as, a few coarse aggregate particles.

Approved by : Submitted by :

Distribution : Mr. E.J. McColm, Mr. P.K. Mukherjee, Mr. J. Vitanyi/Mr. M.F. Everitt
842.5 FRE, Official Record

Report No : SN90-1-K

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE

Project : Frederick House Lake Dam
Region : Northeastern
Area : Timmins
Structure : Frederick House Lake Dam

Job No. : 44-227
File No. : 842.5 FRE
Report No. : SN90-2-K
Date Issued : December 12, 1990

Sample Type : **Core** [X] **Cylinder** [ ] **Chunk** [ ]

Sample Description : Section (depth=10.4 m, nominal 85 mm diameter) from Borehole 1 drilled vertically through gravity section . The concrete has undergone approximately 53 years of exposure in an environment of high relative humidity.

Sample Preparation : **Freshly broken surface** [ ] **Weathered surface** [ ] **Polished face** [X] **Thin Section** [X] / **No.** LTS 63

CONCRETE

Hit with hammer	:	**Ring** [X]	**Dull** [ ]		
Break with fingers	:	**Particles not dislodged** [X]	**Powdery** [ ]	**Friable** [ ]	
During sawing	:	**Clean cut** [X]	**Breaks easily** [ ]		
Cement / coarse aggregate bond	:	**Good** [X]	**Partial** [ ]	**Poor** [ ]	
Cement / fine aggregate bond	:	**Good** [X]	**Partial** [ ]	**Poor** [ ]	
Presence of honeycombing	:	**Not observed** [X]	**Minor** [ ]	**Extensive** [ ]	

COARSE AGGREGATE

Source	: Bedrock from site excavations.			
% of total volume	: 35-40 %	**Visual estimate** [X]	**Point count** [ ]	
Material type	: **Gravel** [ ]	**Quarried** [X]	**Mixture** [ ]	**Other -**
Shape	: **Rounded** [ ]	**Partly crushed** [ ]	**100 % Crushed** [X]	
Distribution	: **Even** [ ]	**Uneven** [X]	**Chaotic** [ ]	
Nominal size	: 28 (mm)			
Maximum size	: 28 (mm)			
Preferred orientation	: **Present** [ ]	**Not observed** [X]		

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS / GEL / FRACTURES	REMARKS
Metavolcanic and metasedimentary migmatites.	95-100	Some of the aggregates are fractured. A few of the fractures extend into the cement paste and are filled with alkali-silica gel.	Moderately to extensively altered. Ferromagnesian minerals have been replaced by chlorite and/or carbonate. White mica and clay minerals have replaced the alkali feldspars.
Trachyte	5	Not observed.	
Gneiss	5	Not observed.	

FINE AGGREGATE

Source	: MTO Map. Inv. No. I02-015. MTO pit P2322-17, Lot 12, Conc. 5, Calvert Twp.			
% of total volume	: 40-45 %	**Visual estimate** [X]	**Point count** [ ]	
Material type	: **Natural** [X]	**Manufactured** [ ]	**Mixture** [ ]	**Other -**
Shape	: **Rounded** [ ]	**Subrounded** [X]	**Subangular** [X]	**Angular** [ ]
Distribution	: **Even** [X]	**Uneven** [ ]	**Chaotic** [ ]	
Preferred orientation	: **Present** [ ]	**Not observed** [X]		

cont.

CEMENT MATRIX

% of total volume : 15-20 % Visual estimate [X] Point count [ ]
Appearance of broken surface : Subtranslucent [X] Dull [ ] Chalky [ ]
Colour : Grey [X] Light Grey [X] White [ ] Brown [ ] Other -
Colour distribution : Even [ ] Mottled [X] Gradational [ ]
Bleeding : Extensive [ ] Minor [ ] Not observed [X]
Carbonation : Surficial only [X] Along fractures [ ] Partial [ ] Total [ ]
Slag cement : Observed [ ] Not observed [X]
Fly ash : Observed [ ] Not observed [X]

VOIDS

% of total volume : 1-3 % Visual estimate [X] Point count [ ]
Distribution : Even [X] Uneven [ ] Clustered [ ]
Shape : Spherical [ ] Nonspherical [ ] Ellipsoidal [ ] Irregular [X]
Entrained air : Air-entrained [ ] Non-air-entrained [X]
Interior lustre : Dull [X] Shining [ ]
Interior condition : Empty [X] Lined [ ] Partly filled [X] Totally filled [ ]
% Voids with mineralization : Most [ ] About half [ ] Few [X] None [ ]
Mineralization : Alkali-silica gel [X] Ettringite [X] Portlandite [ ] Calcium carbonate [ ]

CRACKS

Amount : Extensive [ ] Occasional [X] None [ ]
Continuity and Distribution: A few discontinuous cracks extending across one half the diameter of the specimen.
Orientation : Vertical [ ] Horizontal [X] Random [ ]
Location : Through aggregate particles [X] Around aggregate particles [X]
Width (mm) : Range 0 to 0.5 Average < 0.1
% filled : 35-45 %
Filling material : Alkali-silica gel [X] Ettringite [X] Portlandite [ ]
Calcium carbonate [ ] Other -
Associated with embedded items : Yes [ ] No [X]

EMBEDDED ITEMS Yes [ ] No [X]

Description :
Condition : Clean [ ] Corroded [ ] Decayed [ ]
Size (mm) :
Location / Orientation :
Other :

GENERAL COMMENTS

Most of the voids in the polished specimen are empty. In thin section, many of the voids are lined or partly filled with ettringite while only a few voids are filled with alkali-silica gel. A few sand-sized, chert particles, gelatinized to varying degrees, are present.

Approved by : Submitted by :

Distribution : Mr. E.J. McColm, Mr. P.K. Mukherjee, Mr. J. Vitanyi/Mr. M.F. Everitt
842.5 FRE, Official Record

Report No : SN90-2-K

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE

Project :	Frederick House Lake Dam	**Job No.** :	44-227
Region :	Northeastern	**File No.** :	842.5 FRE
Area :	Timmins	**Report No.** :	SN90-3-K
Structure :	Frederick House Lake Dam	**Date Issued** :	December 12, 1990

Sample Type : **Core** [X] **Cylinder** [ ] **Chunk** [ ]

Sample Description : Section (depth=17.8 m, nominal 85 mm diameter) from Borehole 1 drille vertically through the south gravity section. The concrete has undergone approximately 53 years of exposure in an environment of high relative humidity.

Sample Preparation : **Freshly broken surface** [ ] **Weathered surface** [ ] **Polished face** [X] **Thin Section** [X] / **No.** LTS 64

CONCRETE

Hit with hammer	:	**Ring** [X]	**Dull** [ ]		
Break with fingers	:	**Particles not dislodged** [X]		**Powdery** [ ]	**Friable** [ ]
During sawing	:	**Clean cut** [X]	**Breaks easily** [ ]		
Cement / coarse aggregate bond	:	**Good** [X]	**Partial** [ ]		**Poor** [ ]
Cement / fine aggregate bond	:	**Good** [X]	**Partial** [ ]		**Poor** [ ]
Presence of honeycombing	:	**Not observed** [X]	**Minor** [ ]		**Extensive** [ ]

COARSE AGGREGATE

Source	: Bedrock from site excavations.			
% of total volume	: 35-40%	**Visual estimate** [X]	**Point count** [ ]	
Material type	: **Gravel** [ ]	**Quarried** [X]	**Mixture** [ ]	**Other -**
Shape	: **Rounded** [ ]	**Partly crushed** [ ]	**100 % Crushed** [X]	
Distribution	: **Even** [ ]	**Uneven** [X]	**Chaotic** [ ]	
Nominal size	: 28 (mm)			
Maximum size	: 28 (mm)			
Preferred orientation	: **Present** [ ]	**Not observed** [X]		

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS / GEL / FRACTURES	REMARKS
Metavolcanic and metasedimentary migmatites.	100	Many of the particles have reaction rims of radiating, acicular ettringite needles and alkali-silica gel grading outwards to a carbonated cement paste. These layers are generally less than 0.2 mm wide.	Moderately to extensively altered. Ferromagnesian minerals have been replaced by chlorite and/or carbonate while white mica and clay minerals have replaced alkali feldspars.

FINE AGGREGATE

Source	: MTO Map Inv.No. I02-015. MTO pit P2322-17, Lot 12, Conc. 5, Calvert Twp.			
% of total volume	: 35-40%	**Visual estimate** [X]	**Point count** [ ]	
Material type	: **Natural** [X]	**Manufactured** [ ]	**Mixture** [ ]	**Other -**
Shape	: **Rounded** [ ]	**Subrounded** [X]	**Subangular** [X]	**Angular** [ ]
Distribution	: **Even** [X]	**Uneven** [ ]	**Chaotic** [ ]	
Preferred orientation	: **Present** [ ]	**Not observed** [X]		

cont.

CEMENT MATRIX

% of total volume :	15-20 %	Visual estimate [X]		Point count [ ]	
Appearance of broken surface :		Subtransluscent [X]		Dull [ ]	Chalky [ ]
Colour :	Grey [ ]	Light Grey [X]	White [ ]	Brown [ ]	Other -
Colour distribution :	Even [X]	Mottled [ ]		Gradational [ ]	
Bleeding :	Extensive [ ]	Minor [ ]		Not observed [X]	
Carbonation :	Surficial only [ ]	Along fractures [ ]		Partial [X] (*)	Total [ ]
Slag cement :	Observed [ ]	Not observed [X]			
Fly ash :	Observed [ ]	Not observed [X]			

VOIDS

% of total volume :	1-3 %	Visual estimate [X]		Point count [ ]	
Distribution :	Even [X]	Uneven [ ]		Clustered [ ]	
Shape :	Spherical [ ]	Nonspherical [ ]		Ellipsoidal [ ]	Irregular [X]
Entrained air :	Air-entrained [ ]	Non-air-entrained [X]			
Interior lustre :	Dull [X]	Shining [ ]			
Interior condition :	Empty [X]	Lined [X]		Partly filled [ ]	Totally filled [ ]
% Voids with mineralization :	Most [ ]	About half [ ]		Few [X]	None [ ]
Mineralization :	Alkali-silica gel [ ]	Ettringite [X]		Portlandite [ ]	Calcium carbonate [ ]

CRACKS

Amount : Extensive [ ] Occasional [X] None [ ]

Continuity and Distribution: Discontinuous, tight fractures observable only in thin se ti

Orientation :	Vertical [ ]	Horizontal [ ]		Random [X]
Location :	Through aggregate particles [ ]			Around aggregate particles [X]
Width (mm) :	Range 0 to 0.1	Average ∠0.1		
% filled :	∠10 %			
Filling material :	Alkali-silica gel [ ]	Ettringite [ ]		Portlandite [ ]
	Calcium carbonate [X]	Other -		
Associated with embedded items :	Yes [ ]	No [X]		

EMBEDDED ITEMS Yes [ ] No [X]

Description :
Condition : Clean [ ] Corroded [ ] Decayed [ ]
Size (mm) :
Location / Orientation :
Other :

GENERAL COMMENTS

(*) The surface of many of the coarse aggregate particles is covered with a layer of radiating, needle-like, ettringite crystals and alkali-silica gel. This gel/ ettringite layer is generally less than 0.2 mm wide and grades outwards to a carbonat cement paste, then to a non-carbonated cement paste.

Approved by : Submitted by :

Distribution : Mr. E.J. McColm, Mr. P.K. Mukherjee, Mr. J. Vitanyi/Mr. M.F. Everitt 842.5 FRE, Official Record

Report No : SN90-3-K

APPENDIX D

FREDERICK HOUSE LAKE DAM
GRAVITY SECTION AND SPILLWAY
PETROGRAPHIC EXAMINATION OF CONCRETE CORE

(The cores were obtained in 1991 from the north and south gravity sections and the spillway.)

Note: The appendix in this report has been identified as Appendix A, and this should not be confused with Appendix A of the main report.

91002
new 82-10

Mr. E.J. McColm
Civil Research

ontario hydro
research division

To: Mr. J.B. Brown
Manager
Civil Research Department

Attn: Mr. E.J. McColm

FREDERICK HOUSE LAKE DAM
GRAVITY SECTION AND SPILLWAY
PETROGRAPHIC EXAMINATION OF CONCRETE CORE

M.F. Everitt

1.0 INTRODUCTION

In a previous Research Division Report (S90-47-K) on the petrographic examination of a concrete core drilled from Frederick House Lake Dam, the final paragraph contained the comment: "...It should be noted that these observations apply to the concrete in the vicinity of Borehole 1, and cannot be extrapolated across the entire dam without further study." To investigate how the condition of concrete varies across the dam, additional concrete cores were drilled on June 12, 1991, from the north and south gravity sections and the spillway piers and deck slabs. This report summarizes the petrographic examination of the concrete cores.

2.0 PETROGRAPHIC EXAMINATION

Core locations and logs are included in Research Division Report 91-239-K. The cores selected for petrographic examination can be described briefly as follows:

Core	Location/Description
FH 1	north gravity section
FH 4	pier between deck slabs 4 & 5; concrete exhibited significant map cracking (decks numbered from north to south)
FH 5	downstream portion of deck slab 6; concrete exhibited significant map cracking
FH 6	upstream portion of deck slab 6; concrete exhibited minor map cracking
FH 8	deck slab 9; concrete exhibited significant map cracking
FH 10	south gravity section

The top portion of each core was cut to a length of approximately 150 mm, and the resulting core sections were sawn in half lengthwise. One half of each core section was polished and examined under a stereobinocular microscope. A polished thin section (40 mm x 70 mm) was prepared from the other half and examined under a polarizing light microscope. A detailed petrographic examination of each core section is given in Appendix A.

Concrete from the dam has undergone approximately 54 years of exposure in an outdoor environment of high relative humidity. Except for minor variations in the degree of alkali-aggregate reactivity, the concrete core sections are petrographically similar and are summarized below.

2.1 COARSE AGGREGATE

The coarse aggregate is composed of angular to sub-angular quarried rock. Construction records for this structure indicate that the coarse aggregate was obtained from bedrock excavated at the dam site. The dominant rock types are metasedimentary and metavolcanic migmatites. Most of the rocks have undergone moderate to intense alteration. Principally, ferromagnesian minerals have been replaced by chlorite and/or carbonate, while clay minerals or white mica have replaced the alkali feldspars. The coarse aggregate was petrographically similar to that in the concrete examined from Borehole 1 (Research Division Report S90-47-K).

Fracturing of the coarse aggregate particles was common and is typical of crushed, quarried rock. Some of the fractures were filled with alkali-silica gel. The number of gel filled cracks varied from core to core. The core sections can be ranked in order of decreasing numbers of gel filled cracks as follows: FH4-1, FH10-1, FH1-1, FH8-1, FH5-1, FH6-1.

2.2 FINE AGGREGATE

The fine aggregate was obtained from the Ministry of Transportation, Ontario, pit P2322-17, located on Lot 12, Concession 5, Calvert Township. At the time of construction, this pit was situated on Crown Land. The fine aggregate is made up predominantly of granite gneiss and associated minerals with quartz concentrated in the fine fractions. The fine aggregate is similar to that in the concrete of Borehole 1. Chert particles comprise less than 5% of the fine aggregate and are gelatinized to varying degrees. A few of the chert particles were cracked, with the cracks extending into the cement paste.

2.3 CEMENT PASTE

Most of the core sections examined had a dull, mottled or gradational, grey and light grey, non-air-entrained cement paste. Despite the lack of air entrainment, there is no direct evidence of deterioration of the concrete due to freeze/thaw cycles. The bond between the cement paste and the aggregate is good, indicating that deterioration due to secondary ettringite formation is unlikely, as this would have resulted in a weakening of the bond. Alkali-silica gel was evident in most specimens. In general, the amount of alkali-silica gel in the cement paste showed a direct correlation to the amount of gel filled cracks.

2.4 AIR VOIDS

A few of the air voids in all of the core sections were either lined or totally filled with ettringite. In addition, voids around some aggregate particles in core section FH4-1 were partially or totally filled with alkali-silica gel (See Figure 1).

3.0 ALKALI-AGGREGATE REACTIVITY

Reaction rims were observed around some particles of fine and coarse aggregate. Apart from the gel-lined cracks and a few gel-filled voids (core section FH4-1 only), there is only a minor evidence of deterioration due to alkali-silica reaction.

Two types of alkali-aggregate reactions were observed. One reaction involved the formation of diffusion rims of alkali-silica gel-filled cement paste around aggregate particles. The other reaction consisted of distinct, alkali-silica gel-filled cracks associated with existing fractures within aggregate particles (See Figure 2). No consistent trend towards one type of reaction, either within a core section or between core sections from different locations across the dam, was observed.

4.0 SUMMARY

The concrete from all locations across the dam is petrographically similar. The types of coarse and fine aggregate are the same for all concrete cores examined, including those from Borehole 1.

Some evidence of alkali-silica reaction was found in all the core sections from the north and south gravity sections and spillway piers and deck slabs of Frederick House Lake Dam. The variation of alkali-silica reactions across the dam was not significant, although slightly greater evidence of alkali-silica reactivity was noted in the core section from the pier between deck slabs 4 and 5 (FH4-1). Effects of alkali-silica reactions in the core sections from the gravity sections were similar to the core sections from the pier, except for the absence of gel-filled voids. Core sections from the deck slabs exhibited the lowest degree of alkali-silica reactivity containing only a few gelatinized chert particles.

Approved by:

G.S. Kellay
Supervising Engineer
Concrete Technology Section

MFE:td

Prepared by:

M.F. Everitt
Petrographer
Concrete Technology Section

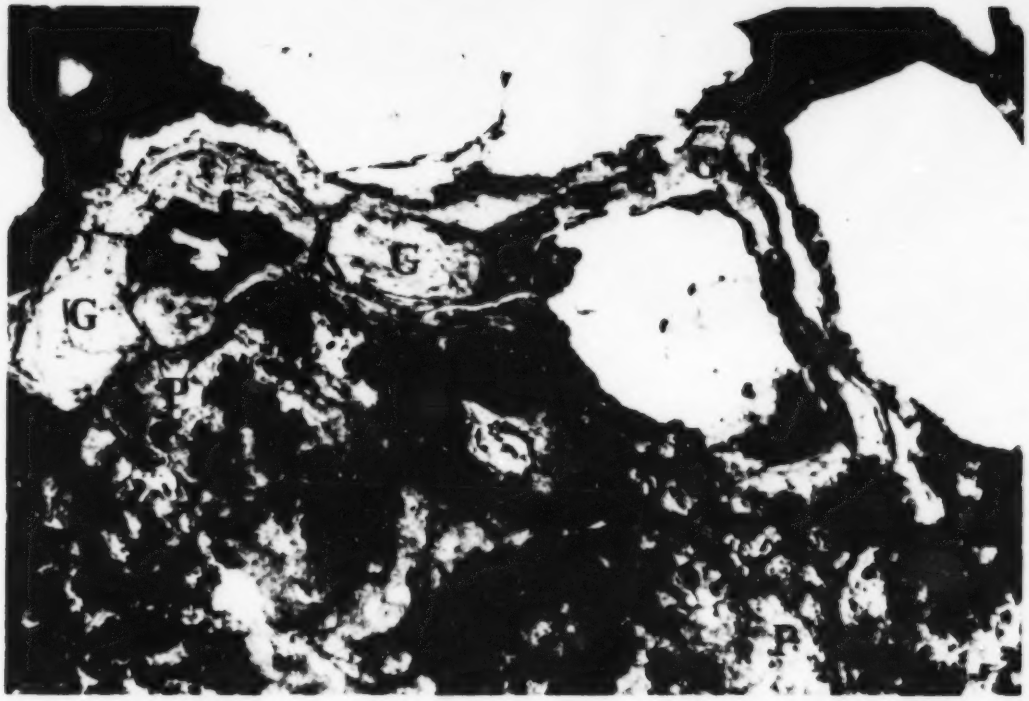


Figure 1. Frederick House Lake Dam: Air void filled with alkali-silica gel (G) at the periphery of a coarse aggregate particle (P). (Analyzer-out, Mag. 32X, LTS 95)

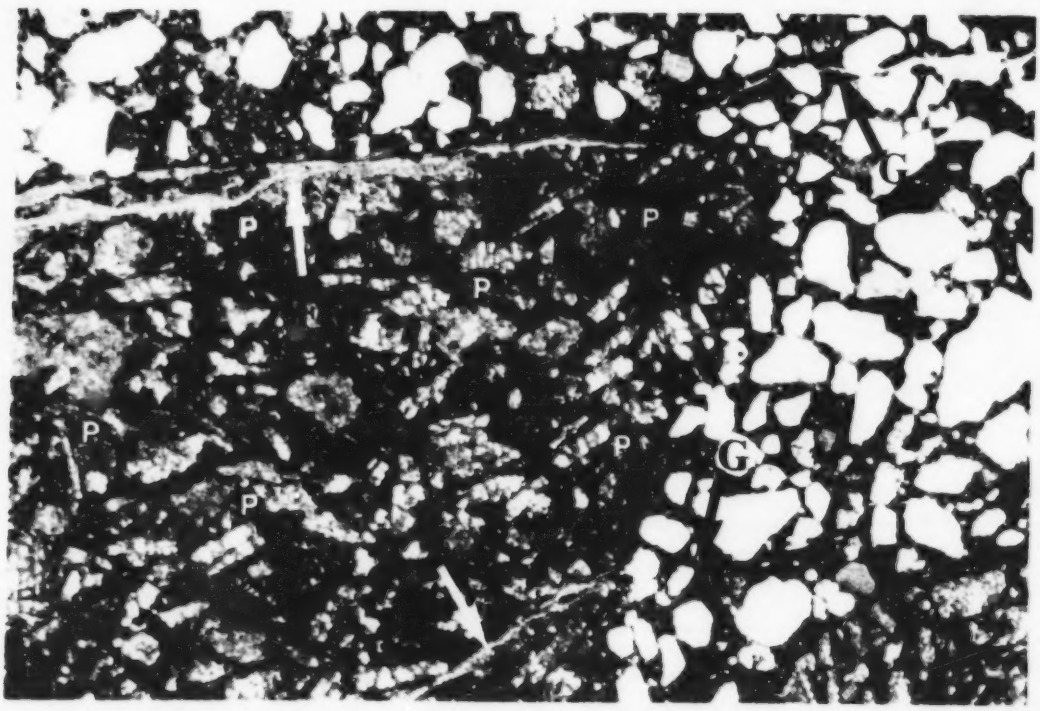


Figure 2: Frederick House Lake Dam: Alkali-silica gel-filled cracks (G) emanating from fractures (F) in coarse aggregate particle (P). (Analyzer-out, Mag. 5.1X, LTS 94)

APPENDIX A

Frederick House Lake Dam

Petrographic Examination of Hardened Concrete

Appendix	Core Section
A1	FH1-1
A2	FH4-1
A3	FH5-1
A4	FH6-1
A5	FH8-1
A6	FH10-1

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE
ADAPTED FROM: ASTM C 856

Project: FREDERICK HOUSE LAKE DAM
Region : NORTHEASTERN Area: TIMMINS Job No.: 42-197-281
Structure: DECK SLAB 6 Report No.: SN91-30-K File No.: 842.5 FRE
Date Issued: 91.08.22

Sample Type : Core[X] Cylinder[ ] Chunk[ ] Other[ ]

Sample Description: Section FH6-1 (interval 0-150 mm, nominal 95 mm diameter) drilled vert. from upstream portion of deck slab 6. The concrete has undergone approx. 54 years of exposure in an outdoor environment of high rel. humidity.

Sample Preparation: Freshly broken/saw cut/drilled surface[ ] Polished face[X]
Weathered surface[ ] Thin Section[X]/No. LTS 97

CONCRETE

Hit with hammer	: Ring[X]	Dull[ ]		
Break with fingers	: Particles not dislodged[X]	Powdery[ ]	Friable[ ]	
During sawing	: Clean cut[X]	Breaks easily[ ]		
Cement/coarse aggregate bond	: Good[X]	Partial[ ]	Poor[ ]	
Cement/fine aggregate bond	: Good[X]	Partial[ ]	Poor[ ]	
Presence of honeycombing	: Not observed[X]	Minor[ ]	Extensive[ ]	

COARSE AGGREGATE

Source	: Bedrock from site excavations.				
% of total volume	: 25-30 %	Visual estimate[X]		Point count[ ]	
Material type	: Gravel[ ]	Quarried[X]	Mixture[ ]	Other[ ]	
Shape	: Rounded[ ]	Partly crushed[ ]		100% Crushed[X]	
Distribution	: Even[ ]	Uneven[X]		Chaotic[ ]	
Nominal size	: 28 (mm)				
Maximum size	: 28 (mm)				
Preferred orientation	: Present[ ]	Not observed[X]			

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS/GEL/ FRACTURES	REMARKS
Metavolcanic and metasedimentary migmatites.	100	A few of the particles are fractured with fractures extending into the cement paste. Alkali-silica gel was not observed in most fractures.	Moderately to extensively altered. Ferromagnesian minerals have been replaced by chlorite and/or carbonate. White mica and clay minerals have replaced the alkali feldspars.

FINE AGGREGATE

Source	: MTO pit P2322-17, Lot 12, Con. 5, Calvert Twp.				
% of total volume	: 35-40 %	Visual estimate[X]		Point count[ ]	
Material type	: Natural[X]	Manufactured [ ]	Mixture[ ]	Other[ ]	
Shape	: Rounded[ ]	Subrounded[X]	Subangular[X]	Angular[ ]	
Distribution	: Even[X]	Uneven[ ]		Chaotic[ ]	
Perferred orientation	: Present[ ]	Not observed[X]			

CEMENT MATRIX

% of total volume : 15-20 % Visual estimate[X] Point count[ ]
Appearance of broken surface: Subtransluescent[ ] Dull[X] Chalky[ ]
Colour : Grey[X] Light grey[X] White[ ] Brown[ ] Other
Colour distribution: Even[ ] Mottled[ ] Gradational[X]
Bleeding : Extensive[ ] Minor[ ] Not observed[X]
Carbonation : Surficial only[ ] Along fractures[X] Partial[X] Total[ ]
Slag cement : Observed[ ] Not observed[X]
Fly ash : Observed[ ] Not observed[X]

VOIDS

% of total volume : 5-7 % Visual estimate[X] Point count[ ]
Distribution : Even[ ] Uneven[X] Clustered[ ]
Shape : Spherical[ ] Nonspherical[X] Ellipsoidal[ ] Irregular[X]
Entrained air : Air-entrained[ ] Non-air-entrained[X]
Interior lustre : Dull[X] Shining[ ]
Interior condition: Empty[X] Lined[X] Partly filled[ ] Totally filled[ ]
% Voids with mineralization: Most[ ] About half[ ] Few[X] None[ ]
Mineralization : Alkali-silica gel[ ] Ettringite[X] Portlandite[ ]
Calcium carbonate[ ]

CRACKS

Amount : Extensive[ ] Occasional[X] None[ ]
Continuity and Distribution: Discontinuous, tight fractures, evenly distributed throughout the specimen. Fractures are primarily between aggregate particles.
Orientation : Vertical[X] Horizontal[ ] Random[X]
Location : Through aggregate particles[X] Around aggregate particles[X]
Width (mm) : Range <0.1 to 0.1 Average < 0.1
% filled : < 10 %
Filling material: Alkali-silica gel[ ] Ettringite[X] Portlandite[ ]
Calcium carbonate[X] Other:
Associated with embedded items: Yes[ ] No[X]

EMBEDDED ITEMS Yes[ ] No[X]

Description:
Condition : Clean[ ] Corroded[ ] Decayed[ ]
Size (mm) :
Location/Orientation:
Other :

GENERAL COMMENTS: Several sand-sized (max. dimension < 5 mm) chert particles, gelatinized to varying degrees, are present.

Distribution: Mr. E.J. McColm Civil Research
Mr. J. Vitanyi Civil Research
Mr. M.F. Everitt Civil Research
842.5 FRE KR163
842.5 (P) Official Record

Approved by: _____ Submitted by: _____
Report No.: SN91-30-K

APPENDIX A2

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE
ADAPTED FROM: ASTM C 856

Project: FREDERICK HOUSE LAKE DAM
Region : NORTHEASTERN
Area: TIMMINS
Structure: DECK SLAB 9
Report No.: SN91-31-K
Job No.: 42-197-281
File No.: 842.5 FRE
Date Issued: 91.08.22

Sample Type : Core[X] Cylinder[ ] Chunk[ ] Other[ ]

Sample Description: Section FH8-1 (interval 0-150 mm, nominal 95 mm diameter) drilled vertically from deck slab 9. The concrete has undergone approx. 54 years of exposure in an outdoor environment of high relative humidity.

Sample Preparation: Freshly broken/saw cut/drilled surface[ ] Polished face[X]
Weathered surface[ ] Thin Section[X]/No. LTS 98

CONCRETE

Hit with hammer	: Ring[X]	Dull[ ]		
Break with fingers	: Particles not dislodged[X]	Powdery[ ]	Friable[ ]	
During sawing	: Clean cut[X]	Breaks easily[ ]		
Cement/coarse aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Cement/fine aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Presence of honeycombing	: Not observed[X]	Minor[ ]		Extensive[ ]

COARSE AGGREGATE

Source	: Bedrock from site excavations.			
% of total volume	: 30-35 %	Visual estimate[X]		Point count[ ]
Material type	: Gravel[ ]	Quarried[X]	Mixture[ ]	Other[ ]
Shape	: Rounded[ ]	Partly crushed[ ]		100% Crushed[X]
Distribution	: Even[ ]	Uneven[X]		Chaotic[ ]
Nominal size	: 28 (mm)			
Maximum size	: 28 (mm)			
Preferred orientation	: Present[X]	Not observed[ ]		

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS/GEL/ FRACTURES	REMARKS
Metavolcanic and metasedimentary migmatites.	100	Several of the particles are fractured with fractures extending into the cement paste. A few fractures are lined with alkali-silica gel. Diffuse rims of alkali-silica gel are common.	Moderately to extensively altered. Ferromagnesian minerals have been replaced by chorite and/or carbonate. White mica and clay minerals have replaced the alkali feldspars.

FINE AGGREGATE

Source	: MTO pit P2322-17, Lot 12, Con. 5, Calvert Twp.			
% of total volume	: 40-45 %	Visual estimate[X]		Point count[ ]
Material type	: Natural[X]	Manufactured [ ]	Mixture[ ]	Other[ ]
Shape	: Rounded[ ]	Subrounded[X]	Subangular[X]	Angular[ ]
Distribution	: Even[X]	Uneven[ ]		Chaotic[ ]
Perferred orientation	: Present[ ]	Not observed[X]		

CEMENT MATRIX

% of total volume : 15-20 % Visual estimate[X] Point count[ ]
Appearance of broken surface: Subtransluescent[ ] Dull[X] Chalky[ ]
Colour : Grey[X] Light grey[X] White[ ] Brown[ ] Other:
Colour distribution: Even[ ] Mottled[X] Gradational[ ]
Bleeding : Extensive[ ] Minor[ ] Not observed[X]
Carbonation : Surficial only[ ] Along fractures[X] Partial[X] Total[ ]
Slag cement : Observed[ ] Not observed[X]
Fly ash : Observed[ ] Not observed[X]

VOIDS

% of total volume : 4-6 % Visual estimate[X] Point count[ ]
Distribution : Even[ ] Uneven[X] Clustered[ ]
Shape : Spherical[ ] Nonspherical[X] Ellipsoidal[ ] Irregular[X]
Entrained air : Air-entrained[ ] Non-air-entrained[X]
Interior lustre : Dull[X] Shining[ ]
Interior condition: Empty[X] Lined[ ] Partly filled[ ] Totally filled[ ]
% Voids with mineralization: Most[ ] About half[ ] Few[X] None[ ]
Mineralization : Alkali-silica gel[ ] Ettringite[X] Portlandite[ ]
Calcium carbonate[ ]

CRACKS

Amount : Extensive[ ] Occasional[X] None[ ]
Continuity and Distribution: Discontinuous, tight fractures throughout the specimen are generally associated with fine lineations of coarse aggregate particles.
Orientation : Vertical[X] Horizontal[ ] Random[X]
Location : Through aggregate particles[X] Around aggregate particles[X]
Width (mm) : Range <0.1 to 0.1 Average < 0.1
% filled : 10-20 %
Filling material: Alkali-silica gel[X] Ettringite[X] Portlandite[ ]
Calcium carbonate[X] Other:
Associated with embedded items: Yes[ ] No[X]

EMBEDDED ITEMS Yes[ ] No[X]

Description:
Condition : Clean[ ] Corroded[ ] Decayed[ ]
Size (mm) :
Location/Orientation:
Other :

GENERAL COMMENTS: A few sand-sized (max. dimension < 5 mm) chert particles, gelatinized to varying degrees, are present.

Distribution: Mr. E.J. McColm Civil Research
Mr. J. Vitanyi Civil Research
Mr. M.F. Everitt Civil Research
842.5 FRE KR163
842.5 (P) Official Record

Approved by: _____ Submitted by: _____
Report No.: SN91-31-K

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE
ADAPTED FROM: ASTM C 856

Project: FREDERICK HOUSE LAKE DAM — Job No.: 42-197-281
Region : NORTHEASTERN — Area: TIMMINS — File No.: 842.5 FRE
Structure: DECK SLAB 6 — Report No.: SN91-29-K — Date Issued: 91.08.22

Sample Type : Core[X] Cylinder[ ] Chunk[ ] Other[ ]

Sample Description: Section FH5-1 (interval 0-155 mm, nominal 95 mm diameter) drilled vert.from downstream portion of deck slab 6.The concrete has undergone approx. 54 years of exposure in an outdoor environment of high rel. humidity.

Sample Preparation: Freshly broken/saw cut/drilled surface[ ] Polished face[X]
Weathered surface[ ] Thin Section[X]/No. LTS 96

CONCRETE

Hit with hammer	: Ring[X]	Dull[ ]		
Break with fingers	: Particles not dislodged[X]	Powdery[ ]	Friable[ ]	
During sawing	: Clean cut[X]	Breaks easily[ ]		
Cement/coarse aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Cement/fine aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Presence of honeycombing	: Not observed[X]	Minor[ ]		Extensive[ ]

COARSE AGGREGATE

Source	: Bedrock from site excavations.			
% of total volume	: 30-35 %	Visual estimate[X]		Point count[ ]
Material type	: Gravel[ ]	Quarried[X]	Mixture[ ]	Other[ ]
Shape	: Rounded[ ]	Partly crushed[ ]		100% Crushed[X]
Distribution	: Even[ ]	Uneven[X]		Chaotic[ ]
Nominal size	: 28 (mm)			
Maximum size	: 28 (mm)			
Preferred orientation	: Present[ ]	Not observed[X]		

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS/GEL/ FRACTURES	REMARKS
Metavolcanic and metasedimentary migmatites.	100	A few particles are fractured with fractures extending into the cement paste.Diffuse rims of alkali-silica gel and/or carbonate were noted on some particles.	Moderately to extensively altered.Ferromagnesian minerals have been replaced by chlorite and/or carbonate.White mica and clay minerals have replaced the alkali feldspars.

FINE AGGREGATE

Source	: MTO pit P2322-17, Lot 12, Con. 5, Calvert Twp.				
% of total volume	: 35-40 %	Visual estimate[X]			Point count[ ]
Material type	: Natural[X]	Manufactured [ ]	Mixture[ ]		Other[ ]
Shape	: Rounded[ ]	Subrounded[X]	Subangular[X]		Angular[ ]
Distribution	: Even[X]	Uneven[ ]			Chaotic[ ]
Perferred orientation	: Present[ ]	Not observed[X]			

CEMENT MATRIX

% of total volume : 20-25 % Visual estimate[X] Point count[ ]
Appearance of broken surface: Subtransluescent[ ] Dull[X] Chalky[ ]
Colour : Grey[X] Light grey[X] White[ ] Brown[ ] Other:
Colour distribution: Even[ ] Mottled[ ] Gradational[X]
Bleeding : Extensive[ ] Minor[ ] Not observed[X]
Carbonation : Surficial only[ ] Along fractures[X] Partial[ ] Total[ ]
Slag cement : Observed[ ] Not observed[X]
Fly ash : Observed[ ] Not observed[X]

VOIDS

% of total volume : 1-3 % Visual estimate[X] Point count[ ]
Distribution : Even[ ] Uneven[X] Clustered[ ]
Shape : Spherical[ ] Nonspherical[ ] Ellipsoidal[ ] Irregular[X]
Entrained air : Air-entrained[ ] Non-air-entrained[X]
Interior lustre : Dull[X] Shining[ ]
Interior condition: Empty[X] Lined[X] Partly filled[X] Totally filled[ ]
% Voids with mineralization: Most[ ] About half[ ] Few[X] None[ ]
Mineralization : Alkali-silica gel[X] Ettringite[ ] Portlandite[X]
Calcium carbonate[X]

CRACKS

Amount : Extensive[ ] Occasional[X] None[ ]
Continuity and Distribution: Discontinuous, tight fractures throughout the specimen are generally associated with fine lineations of coarse aggregate particles.
Orientation : Vertical[X] Horizontal[ ] Random[X]
Location : Through aggregate particles[X] Around aggregate particles[X]
Width (mm) : Range <0.1 to 0.1 Average < 0.1
% filled : 10-20 %
Filling material: Alkali-silica gel[X] Ettringite[X] Portlandite[ ]
Calcium carbonate[X] Other:
Associated with embedded items: Yes[ ] No[X]

EMBEDDED ITEMS Yes[ ] No[X]

Description:
Condition : Clean[ ] Corroded[ ] Decayed[ ]
Size (mm) :
Location/Orientation:
Other :

GENERAL COMMENTS: Several sand-sized (max. dimension < 5 mm) chert particles, gelatinized to varying degrees, are present.

Distribution: Mr. E.J. McColm Civil Research
Mr. J. Vitanyi Civil Research
Mr. M.F. Everitt Civil Research
842.5 FRE KR163
842.5 (P) Official Record

Approved by: _____ Submitted by: _____
Report No.: SN91-29-K

APPENDIX A4

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE
ADAPTED FROM: ASTM C 856

Project: FREDERICK HOUSE LAKE DAM — Job No.: 42-197-281
Region : NORTHEASTERN — Area: TIMMINS — File No.: 842.5 FRE
Structure: PIER WEST OF SLAB 4 — Report No.: SN91-28-K — Date Issued: 91.08.22

Sample Type : Core[X] Cylinder[ ] Chunk[ ] Other[ ]

Sample Description: Section FH4-1 (interval 0-150 mm, nominal 95 mm diameter) drilled vertically from pier between deck slabs 4&5.The concrete has undergone approx. 54 years of exposure in an outdoor environment of high rel. humidity.

Sample Preparation: Freshly broken/saw cut/drilled surface[ ] Polished face[X]
Weathered surface[ ] Thin Section[X]/No. LTS 95

CONCRETE

Hit with hammer	: Ring[X]	Dull[ ]		
Break with fingers	: Particles not dislodged[X]	Powdery[ ]	Friable[ ]	
During sawing	: Clean cut[X]	Breaks easily[ ]		
Cement/coarse aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Cement/fine aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Presence of honeycombing	: Not observed[X]	Minor[ ]		Extensive[ ]

COARSE AGGREGATE

Source	: Bedrock from site excavations.				
% of total volume	: 25-30 %	Visual estimate[X]			Point count[ ]
Material type	: Gravel[ ]	Quarried[X]	Mixture[ ]		Other[ ]
Shape	: Rounded[ ]	Partly crushed[ ]			100% Crushed[X]
Distribution	: Even[ ]	Uneven[X]			Chaotic[ ]
Nominal size	: 28 (mm)				
Maximum size	: 28 (mm)				
Preferred orientation	: Present[ ]	Not observed[X]			

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS/GEL/ FRACTURES	REMARKS
Metavolcanic and metasedimentary migmatites.	100	Most of the particles are rimmed with alkali-silica gel.Voids around some particles are filled or lined with alkali-silica gel.Several of the particles are fractured with fractures extending into the cement paste.	Moderately to extensively altered.Ferromagnesian minerals have been replaced by chlorite and/or carbonate.White mica and clay minerals have replaced the alkali feldspars.

FINE AGGREGATE

Source	: MTO pit P2322-17, Lot 12, Con. 5, Calvert Twp.				
% of total volume	: 40-45 %	Visual estimate[X]			Point count[ ]
Material type	: Natural[X]	Manufactured [ ]	Mixture[ ]		Other[ ]
Shape	: Rounded[ ]	Subrounded[X]	Subangular[X]		Angular[ ]
Distribution	: Even[X]	Uneven[ ]			Chaotic[ ]
Perferred orientation	: Present[ ]	Not observed[X]			

CEMENT MATRIX

% of total volume : 15-20 % Visual estimate[X] Point count[ ]
Appearance of broken surface: Subtransluescent[ ] Dull[X] Chalky[ ]
Colour : Grey[X] Light grey[X] White[ ] Brown[ ] Other:
Colour distribution: Even[ ] Mottled[X] Gradational[ ]
Bleeding : Extensive[ ] Minor[ ] Not observed[X]
Carbonation : Surficial only[ ] Along fractures[X] Partial[ ] Total[ ]
Slag cement : Observed[ ] Not observed[X]
Fly ash : Observed[ ] Not observed[X]

VOIDS

% of total volume : 1-3 % Visual estimate[X] Point count[ ]
Distribution : Even[ ] Uneven[X] Clustered[ ]
Shape : Spherical[ ] Nonspherical[ ] Ellipsoidal[ ] Irregular[X]
Entrained air : Air-entrained[ ] Non-air-entrained[X]
Interior lustre : Dull[X] Shining[ ]
Interior condition: Empty[X] Lined[X] Partly filled[X] Totally filled[X]
% Voids with mineralization: Most[ ] About half[X] Few[ ] None[ ]
Mineralization : Alkali-silica gel[X] Ettringite[ ] Portlandite[ ]
Calcium carbonate[X]

CRACKS

Amount : Extensive[ ] Occasional[X] None[ ]
Continuity and Distribution: Discontinuous cracks, uniformly distributed throughout the specimen. A vertical crack extends from the surface to a depth of approx. 80 mm.
Orientation : Vertical[X] Horizontal[ ] Random[X]
Location : Through aggregate particles[X] Around aggregate particles[X]
Width (mm) : Range <0.1 to 0.1 Average < 0.1
% filled : 20-30 %
Filling material: Alkali-silica gel[X] Ettringite[ ] Portlandite[ ]
Calcium carbonate[X] Other:
Associated with embedded items: Yes[ ] No[X]

EMBEDDED ITEMS Yes[ ] No[X]

Description:
Condition : Clean[ ] Corroded[ ] Decayed[ ]
Size (mm) :
Location/Orientation:
Other :

GENERAL COMMENTS: Several sand-sized (max. dimension < 5 mm) chert particles, gelatinized to varying degrees, are scattered throughout the concrete.

Distribution: Mr. E.J. McColm Civil Research
Mr. J. Vitanyi Civil Research
Mr. M.F. Everitt Civil Research
842.5 FRE KR163
842.5 (P) Official Record

Approved by: _____ Submitted by: _____
Report No.: SN91-28-K

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE
ADAPTED FROM: ASTM C 856

Project: FREDERICK HOUSE LAKE DAM — Job No.: 42-197-281
Region : NORTHEASTERN — Area: TIMMINS — File No.: 842.5 FRE
Structure: NORTH GRAVITY SECT. — Report No.: SN91-27-K — Date Issued: 91.08.22

Sample Type : Core[X] Cylinder[ ] Chunk[ ] Other[ ]

Sample Description: Section FH1-1 (interval 0-150 mm, nominal 95 mm diameter) drilled vertically from the north gravity section. The concrete has undergone approx. 54 years of exposure in an outdoor environment of high rel. humidity.

Sample Preparation: Freshly broken/saw cut/drilled surface[ ] Polished face[X]
Weathered surface[ ] Thin Section[X]/No. LTS 94

CONCRETE

Hit with hammer	: Ring[X]	Dull[ ]		
Break with fingers	: Particles not dislodged[X]	Powdery[ ]	Friable[ ]	
During sawing	: Clean cut[X]	Breaks easily[ ]		
Cement/coarse aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Cement/fine aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Presence of honeycombing	: Not observed[X]	Minor[ ]		Extensive[ ]

COARSE AGGREGATE

Source	: Bedrock from site excavations.				
% of total volume	: 30-35 %	Visual estimate[X]		Point count[ ]	
Material type	: Gravel[ ]	Quarried[X]	Mixture[ ]	Other[ ]	
Shape	: Rounded[ ]	Partly crushed[ ]		100% Crushed[X]	
Distribution	: Even[ ]	Uneven[X]		Chaotic[ ]	
Nominal size	: 28 (mm)				
Maximum size	: 28 (mm)				
Preferred orientation	: Present[X]	Not observed[ ]			

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS/GEL/ FRACTURES	REMARKS
Metavolcanic and metasedimentary migmatites.	100	Many of the particles have diffuse rims of alkali-silica gel. Most of the particles are fractured with fractures extending into the cement paste. Many of the fractures are filled with alkali-silica gel.	Moderately to extensively altered. Ferromagnesian minerals have been replaced by chlorite and/or carbonate White mica and clay minerals have replaced the alkali feldspars.

FINE AGGREGATE

Source	: MTO pit P2322-17, Lot 12, Con. 5, Calvert Twp.				
% of total volume	: 40-45 %	Visual estimate[X]		Point count[ ]	
Material type	: Natural[X]	Manufactured [ ]	Mixture[ ]	Other[ ]	
Shape	: Rounded[ ]	Subrounded[X]	Subangular[X]	Angular[ ]	
Distribution	: Even[X]	Uneven[ ]		Chaotic[ ]	
Perferred orientation	: Present[ ]	Not observed[X]			

CEMENT MATRIX

% of total volume : 15-20 % Visual estimate[X] Point count[
Appearance of broken surface: Subtransluescent[ ] Dull[X] Chalky[
Colour : Grey[X] Light grey[X] White[ ] Brown[ ] Other:
Colour distribution: Even[ ] Mottled[ ] Gradational[X]
Bleeding : Extensive[ ] Minor[X] Not observed[
Carbonation : Surficial only[ ] Along fractures[X] Partial[ ] Total[
Slag cement : Observed[ ] Not observed[X]
Fly ash : Observed[ ] Not observed[X]

VOIDS

% of total volume : 1-3 % Visual estimate[X] Point count[
Distribution : Even[ ] Uneven[X] Clustered[
Shape : Spherical[ ] Nonspherical[X] Ellipsoidal[ ] Irregular[X]
Entrained air : Air-entrained[ ] Non-air-entrained[X]
Interior lustre : Dull[X] Shining[ ]
Interior condition: Empty[X] Lined[X] Partly filled[ ] Totally filled[
% Voids with mineralization: Most[ ] About half[ ] Few[X] None[
Mineralization : Alkali-silica gel[X] Ettringite[X] Portlandite[ ]
Calcium carbonate[ ]

CRACKS

Amount : Extensive[ ] Occasional[X] None[
Continuity and Distribution: Discontinuous fractures are evenly distributed throughout the sample.

Orientation : Vertical[ ] Horizontal[ ] Random[X
Location : Through aggregate particles[X] Around aggregate particles[X
Width (mm) : Range <0.1 to 0.2 Average < 0.1
% filled : 15-20 %
Filling material: Alkali-silica gel[X] Ettringite[X] Portlandite[
Calcium carbonate[X] Other:
Associated with embedded items: Yes[ ] No[X]

EMBEDDED ITEMS Yes[ ] No[X]

Description:
Condition : Clean[ ] Corroded[ ] Decayed[
Size (mm) :
Location/Orientation:
Other :

GENERAL COMMENTS: Major cracks are associated with veins of microcrystalline quartz in coarse aggregate particles. Several sand-sized, chert particles, gelatinized to varying degrees, are present.

Distribution: Mr. E.J. McColm Civil Research
Mr. J. Vitanyi Civil Research
Mr. M.F. Everitt Civil Research
842.5 FRE KR163
842.5 (P) Official Record

Approved by: _____ Submitted by: _____
Report No.: SN91-27-K

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE
ADAPTED FROM: ASTM C 856

Project: FREDERICK HOUSE LAKE DAM — Job No.: 42-197-281
Region : NORTHEASTERN — Area: TIMMINS — File No.: 842.5 FRE
Structure: SOUTH GRAVITY SECT. — Report No.: SN91-32-K — Date Issued: 91.08.22

Sample Type : Core[X] Cylinder[ ] Chunk[ ] Other[ ]

Sample Description: Section FH10-1 (interval 0-150 mm, nominal 95 mm diameter) drilled vertically from the south gravity section. The concrete has undergone approx. 54 years of exposure in an outdoor environment of high rel. humidity.

Sample Preparation: Freshly broken/saw cut/drilled surface[ ] Polished face[X]
Weathered surface[ ] Thin Section[X]/No. LTS 99

CONCRETE

Hit with hammer	: Ring[X]	Dull[ ]		
Break with fingers	: Particles not dislodged[X]	Powdery[ ]	Friable[ ]	
During sawing	: Clean cut[X]	Breaks easily[ ]		
Cement/coarse aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Cement/fine aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Presence of honeycombing	: Not observed[ ]	Minor[X]		Extensive[ ]

COARSE AGGREGATE

Source	: Bedrock from site excavations.			
% of total volume	: 15-20 %	Visual estimate[X]		Point count[ ]
Material type	: Gravel[ ]	Quarried[X]	Mixture[ ]	Other[ ]
Shape	: Rounded[ ]	Partly crushed[ ]		100% Crushed[X]
Distribution	: Even[ ]	Uneven[X]		Chaotic[ ]
Nominal size	: 28 (mm)			
Maximum size	: 28 (mm)			
Preferred orientation	: Present[ ]	Not observed[X]		

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS/GEL/ FRACTURES	REMARKS
Metavolcanic and metasedimentary migmatites.	100	Several of the particles are rimmed with alkali-silica gel and/or carbonate. Many of the particles are fractured with fractures extending into the cement paste. Voids around a few particles contain gel.	Moderately to extensively altered. Ferromagnesian minerals have been replaced by chlorite and/or carbonate. White mica and clay minerals have replaced the alkali feldspars.

FINE AGGREGATE

Source	: MTO pit P2322-17, Lot 12, Con. 5, Calvert Twp.				
% of total volume	: 40-45 %	Visual estimate[X]			Point count[ ]
Material type	: Natural[X]	Manufactured [ ]	Mixture[ ]		Other[ ]
Shape	: Rounded[ ]	Subrounded[X]	Subangular[X]		Angular[ ]
Distribution	: Even[X]	Uneven[ ]			Chaotic[ ]
Perferred orientation	: Present[ ]	Not observed[X]			

CEMENT MATRIX

% of total volume : 20-25 % Visual estimate[X] Point count[ ]
Appearance of broken surface: Subtransluescent[ ] Dull[X] Chalky[ ]
Colour : Grey[X] Light grey[X] White[ ] Brown[ ] Other:
Colour distribution: Even[ ] Mottled[X] Gradational[ ]
Bleeding : Extensive[ ] Minor[ ] Not observed[X]
Carbonation : Surficial only[ ] Along fractures[ ] Partial[X] Total[ ]
Slag cement : Observed[ ] Not observed[X]
Fly ash : Observed[ ] Not observed[X]

VOIDS

% of total volume : 3-5 % Visual estimate[X] Point count[ ]
Distribution : Even[ ] Uneven[X] Clustered[ ]
Shape : Spherical[ ] Nonspherical[ ] Ellipsoidal[ ] Irregular[X]
Entrained air : Air-entrained[ ] Non-air-entrained[X]
Interior lustre : Dull[X] Shining[ ]
Interior condition: Empty[X] Lined[X] Partly filled[X] Totally filled[X]
% Voids with mineralization: Most[ ] About half[ ] Few[X] None[ ]
Mineralization : Alkali-silica gel[X] Ettringite[X] Portlandite[ ]
Calcium carbonate[X]

CRACKS

Amount : Extensive[ ] Occasional[X] None[ ]
Continuity and Distribution: Several vertical cracks extend from the surface to a depth of approx. 60 mm. Most cracks are discontinuous and distributed throughout the core
Orientation : Vertical[X] Horizontal[ ] Random[X]
Location : Through aggregate particles[X] Around aggregate particles[X]
Width (mm) : Range <0.2 to 0.4 Average < 0.2
% filled : 20-30 %
Filling material: Alkali-silica gel[X] Ettringite[X] Portlandite[ ]
Calcium carbonate[X] Other:
Associated with embedded items: Yes[ ] No[X]

EMBEDDED ITEMS Yes[ ] No[X]

Description:
Condition : Clean[ ] Corroded[ ] Decayed[ ]
Size (mm) :
Location/Orientation:
Other :

GENERAL COMMENTS: Several sand-sized (max. dimension < 5 mm) chert particles, gelatinized to varying degrees, are present.

Distribution: Mr. E.J. McColm Civil Research
Mr. J. Vitanyi Civil Research
Mr. M.F. Everitt Civil Research
842.5 FRE KR163
842.5 (P) Official Record

Approved by: _____ Submitted by: _____
Report No.: SN91-32-K